

Operational Shock and Complexity Theory

A Monograph

by

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Abstract

OPERATIONAL SHOCK AND COMPLEXITY THEORY by Major Paul J. Blakesley, British Army, 108 pages.

From the Classical Period until the Seventeenth century, the study of warfare was practiced predominantly using the vehicle of history. The scientific revolution, ushered in by Newtonian laws, had a major impact on Western military thinking. By believing in the power of reductionism, planners were taught to decompose problems into their constituent parts and solve them, almost in isolation. This analysis was followed by a synthesis of the constituent parts in order to solve the problem. Newtonian science began to falter at the beginning of the Twentieth century with the advent of systems theory. Complexity theory developed from the study of complex adaptive systems that exhibited a self-organizing capability that prevented them from slipping into chaos. A complex system adapts to its surroundings and learns from its interactions. This learning enables the system to maximize its position vis-à-vis its environment and can lead to an emergence of a new and unexpected system that cannot be predicted from the original elements. These new sciences stress non-linearity and the need to view problems holistically.

The United States, by developing some of the best-trained and technologically equipped soldiers in the world, has exponentially reduced the chance of it fighting a high intensity conflict in the near or medium future. Ironically, the mastery of this type of warfare has forced others to alter their conduct of warfare. There has been a resurgence in challenges by non-state actors, something not seen for centuries.

Military Operations exhibit the signs indicative of complex behavior. Despite recognizing the change in the environment and the enemy, US Army doctrine is still rooted in the symmetrical battle concept and many current theoretical models do not adequately deal with the increasing complexity of war, including the concept of operational shock. Because of the mechanistic reductionism, the models do not lend themselves to future combat situations where emergent systems will be the norm. Military science needs to embrace this new framework. This monograph suggests that the analysis of complexity and chaos can provide a framework for operational shock. Beginning with an introduction to complexity theory, the monograph examines the issue of emergence over time and the various methods available to planners to degrade an enemy system while protecting their own. Finally, it makes recommendations for the future construct of the United States military using the Doctrine, Organization, Training, Materiel, Leadership, Personnel and Facilities (DOTMLPF) structure.

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Introduction

One way or another, the days of short, successful, pain-free Western military operations against relatively minor states will probably be short-lived.¹

War is a complex phenomenon according to any practical definition of the term “complexity.”² Historians argue about when warfare ceased being predominantly linear but, over the last century, the conduct of warfare has become more complex. Technology, the environment, and the enemy have driven this change.³ The result of continued study into systems, chaos and complexity theory has also changed our perception of the world from that of Newtonian reductionism to nonlinear models. Nonlinearity complicates issues as “the act of playing the game has a way of changing the rules.”⁴ Within this turbulence, doctrine must evolve or risk becoming obsolete.⁵

Despite recognizing the opportunities and threats that the 21st Century presents, elements of United States (US) doctrine appear rooted in the symmetrical battle concept, and many current theoretical models do not adequately deal with the increasing complexity of war.⁶ This

¹ C. J. Dick, “Conflict in a Changing World: Looking Two Decades Forward.” *European Security*, Vol. 11, No. 3 (Autumn 2002): 28.

² John F. Schmitt, “Command and (Out of) Control: The Military Implications of Complexity Theory,” in *Complexity, Global Politics and National Security*. (Edited by David S. Alberts and Tom Czerwinski. Washington D.C.: National Defense University 1997), 4. Complexity theory will be described in detail in chapter 2, but as an overview, war is an exchange of matter, information and energy between at least two organizations, often occurring at many levels simultaneously. These engagements take place in a nonlinear environment. War can not be captured in one place at one time, nor can its nature be summed up by one “snapshot” of a situation. These are some of the characteristics of complex systems. Complexity should not be confused with a set of complex scenarios, which can be broken down into constituent parts. This difference will be covered in chapter 2. Land Warfare is certainly more complex than its rivals of sea and air war, and more reliant on psychological elements.

³ This monograph will only touch on a couple of the areas of change and why the concept of operational shock must evolve. The reader is directed to the United States Joint Forces Command, *The Joint Operational Environment – Into the Future*. United States Joint Forces Command J2, March 2004.

⁴ James Gleick, *Chaos – Making a New Science* (New York: Penguin Books, 1997), 24.

⁵ James K. Greer “Operational Art for The Objective Force.” *Military Review* Vol. 82, Iss. 5 (September/October 2002): 23. Greer claims that the current operational design construct is incapable of providing planners the means of designing campaigns for full spectrum operations.

⁶ There are many reasons for this. Two of the most important are that for the majority of the last century when the US concentrated on a foreign policy it was within the bipolar world of the Cold War, and that US industrial and technological prowess allows for a war to be won through the concept of attrition and exhaustion. Indeed one of the reasons for the collapse of the Soviet Union is attributed to the sheer inability of its economic system to out produce America’s.

monograph examines the concept of operational shock by using a systems approach that integrates complexity theory. The aim is to provide an understanding of the role of complexity therein. Linear thinking, attributed primarily to Newton, hinged on three main assumptions: linearity and proportionality of cause and effect; the whole being the sum of the parts (additivity); and the belief in perfect prediction being possible with perfect measurements.⁷ Military systems are categorized as being nonlinear and inherently complex as they contravene these assumptions.⁸

Complexity is not easy to define; a close approximation is when “a great many independent agents are interacting with each other in a great many ways.”⁹ Within this concept all complex systems are both spontaneously self-organizing and naturally adaptive. The self-organizing occurs without any omniscient being controlling events, and the ability to adapt is necessary to prevent the system from becoming predictable, and thus vulnerable. This self-organizing also leads to the individuals and the system being able to take advantage of new opportunities that emerge through their interactions. These interactions often lead to the formation of small groups that then in turn interact with other groups of individuals. This process continues creating larger and larger groups, leading to the occurrence of emergence of a set of properties and behaviors that was not predictable by analyzing the individual parts.¹⁰

These individuals (and the groups they form) need to ensure that they learn from the past as well as attempt to forecast or predict the future if they are to take advantage of the

⁷ Alan Beyerchen, “Clausewitz, Nonlinearity and the Unpredictability of War.” *International Security* Vol. 17, No. 3 (Winter 1992/93): 62. There is also the issue of a linear system being replicable which is not included in the Beyerchen article. As an aside it is perhaps a little unfair to tar Newton with being the harbinger of linear thinking. If anyone is to blame, one should look at the philosopher Laplace who argued for a deterministic view of philosophy. That aside the concept that a linear process coupled with perfect knowledge offered was that of the ability to control, hence explaining why so many militaries have pursued this avenue.

⁸ They are non-linear because outputs are not always proportional to inputs, and they exhibit the property of synergy. They are also highly sensitive to initial conditions (SIC).

⁹ Mitchell M. Waldrop, *Complexity: The Emerging Science at the Edge of Order and Chaos* (New York: Touchstone, 1992), 11.

¹⁰ This emergence is why reductionism will not work. The very act of breaking the system down into its constituent parts will alter the interrelationships and thus change the system. By trying to make it simpler one makes it different.

environment. This predictive ability comes from an internal model that updates after exposure to planned actions and actual outcomes. In short, both the system and the individual learn. This process, in the most general of terms, is the concept of feedback. Only by maintaining a feedback loop (that is by observing what previous events caused what outcomes) can the system hope to build a model of the future.¹¹ This feedback is both internal (a model based on ideas of linkages which learns as time goes on) and external (from the environment and responses observed from each input). While each individual and subsystem is attempting to maximize its iteration in this cycle, all of the other (possibly competing) individuals and groups are doing the same. Thus to some extent it is a battle between entities in an imperfect information model where the ability to observe the result of one's actions vis-à-vis one's competitors is crucial. This makes the system not merely complicated (as a snowflake or a micro chip is considered complicated) but dynamic.¹²

It is possible by manipulating feedback to force a complex adaptive system (CAS) to make sub-optimal decisions. This is achieved by altering its internal model and thus ultimately dominating it. Dependent on the system's degree of complexity it will have a limited number of responses built in its model. As the system develops, learns and becomes more complex, the number of these "plays" available will increase. However, as the environment is competitive, every other system is also learning. Thus, it is possible for another system that is more complex to either have more plays available or simply to have a better internal model. This more complex system will have more variety than its opposition and will be able to outmaneuver the less agile one.¹³

¹¹ Of course, there is the issue of the ability of any individual or system to identify fully the causality. An incorrect causal relationship if used within the model will cause a sub optimal decision to be made later. This offers an opportunity to manipulate the system, which will be considered in chapter 3.

¹² Ibid., 11-13. It is important to note that this dynamism is not chaotic. This issue is discussed in more depth in chapter 2.

¹³ This concept is the basis for Ashby's law and will be discussed in the next chapter.

The Changing Environment

The more complex and dynamic an environment, the more important adaptation is. The future operating environment is very complex. Current predictions about the global future range from the rosy picture envisaged by globalization proponents such as Thomas Friedman to the gloomy outlook of Robert Kaplan and Samuel Huntington.¹⁴ The balance is probably somewhere in the middle. What is without question is that this new world order will see more deployment of coalition and US forces all over the world. These forces will conduct military operations that fall short of general war and probably involve typically non-military operations (such as nation building).

Why Is Any Of This Important?

The US since World War II has found itself increasingly duty bound to intervene abroad, either by choice or by request. This intervention has generally been to enforce international laws; seize transnational terrorist organizations; to prevent a government using its own forces for genocide; and finally to reinstate a government deposed by force.¹⁵ Despite this, the major threat remained a Soviet invasion of Europe, and so the US developed its tactical and operational doctrine to destroy an echeloned foe throughout its depth.¹⁶

The Bush Administration stressed in its 2002 National Military Strategy the principal right of a state to defend itself by preemption.¹⁷ This doctrine of preemption has undoubtedly

¹⁴ Thomas L. Friedman, *Lexus and The Olive Tree*, New York: First Anchor Books Edition, 2000. Robert Kaplan, *The Coming Anarchy – Shattering the Dreams of the Post Cold War Era*, New York: Vintage Books, A Division of Random House Inc., 2001, and Samuel P. Huntington, *The Clash of Civilisations and the Remaking of World Order*, New York: Simon and Schuster, 1996.

¹⁵ Huba Wass de Czerge, “Why We Need a Strong Army,” *Army Magazine*, Vol. 54, No. 2 (February 2004): 46.

¹⁶ There were many reasons for this, not least the failure in Vietnam during the 1970s during which time the Soviets achieved a large advantage over the US in terms of force numbers and equipment capabilities.

¹⁷ President George W. Bush highlighted his ideas of preemption during his both his State of The Union Speech in 2002 and his speech at West Point in May 2002. The 2002 National Military Strategy built on the generally accepted view of preemption (the use of force reacting to an imminent attack) and

committed the military to both extensive deployments in many areas of the globe previously not considered, as well as fighting many different enemies. The challenge is not simply the number and variety of deployments, but of facing groups who may not share the same operating characteristics and who have not developed along the same lines.¹⁸

Current trends within the world do not disprove this.¹⁹ Recent involvement by the United States has been less in the traditional form of defeating an overt and recognizable enemy and more in the realm of dealing with non-state actors, guerilla forces and terrorist networks. This involvement may also concentrate less on winning and more on not losing against actors who will attempt to dissuade US interference by any means.²⁰ Doctrine must therefore adjust to this different type of warfare as opposed to simply fitting its old concepts to the new problems.²¹ If it does not, this shift from a “clean” environment in which conventional forces could conduct “fair” force on force warfare may herald the end of the superiority of the current Western Way of Warfare.²²

As Professor John A. Lynn states, “a fundamentally different kind of military threat requires us to rethink our military policy, the purpose of our armed forces, and the nature of war

broadened it to encompass preventive war, where force may be used without the full burden of proof of imminent attack. The idea is to prevent an enemy from developing a threat to the US over time.

¹⁸ It is feasible to suggest that each enemy group will have different internal models, and thus will react differently to changes in their environment

¹⁹ Dick, 24. With the reliance on markets outside of its borders, the US economy has spun a web of commercial, cultural, political and security too valuable to its future ties simply to walk away. Perhaps more frightening is the chaos that would descend should the US decide to accept the reduction in living standards and become isolationist.

²⁰ Jacob Kipp, “Russia’s Nonstrategic Nuclear Weapons” *Military Review* Vol. 81, No. 3 (May/Jun 2001): 27-39. This may manifest itself from guerrilla and terrorist like operations once the US has deployed to entry denial operations with nonstrategic nuclear weapons (NSNW). Kipp believes that technically inferior, but nuclear capable, adversaries will perceive the threshold for the use of NSNWs lowered as a solution to their inadequacies in what he calls “sixth generation warfare.”

²¹ Peter M. Senge, *The Fifth Discipline – The Art and Practice of the Learning Organization*, (New York: Currency Doubleday, 1994), 61. Senge claims on this page that “pushing harder and harder on familiar solutions,..., is a reliable indicator of nonsystemic thinking.”

²² There is some debate over the distinction between Western and Eastern Ways of War. For the purposes of this monograph, the Western Way of War is typified as a symmetric force on force battle, between identifiable combatants representing Nation States. For an in-depth discussion of the differing views on this topic, see John A. Lynn, *Battle. A History of Combat and Culture*, Colorado: Westview Press, 2003.

itself.”²³ Despite this change in threat, environment and the emergence of complexity and systems theory, US doctrine is still rooted firmly in the ideas of von Clausewitz, Jomini, and Fuller as well as the concept of the decisive battle and checklists.²⁴ The reason for this resistance to change is beyond the scope of this monograph, but lies essentially at the door of the Westerner’s perceived need for order, theory and lack of belief in the concept of fate.²⁵

Finally, complexity offers a mixture of threat and opportunity for the armed force of tomorrow. The presence of nonlinearity allows small effects to create large outcomes; instability can be injected into systems to cause their subsequent failure. Another option is the ability to be able to manipulate an enemy’s feedback loop. This will either force them either towards equilibrium, or to expend more energy on remaining within the zone of complexity. Given that a system has a finite amount of energy the system will have to reduce the amount it is expending on attacking, or face death. Complexity theory may also provide the US Armed Forces with a real bargaining tool as to why training to increase flexibility and adaptability must continue.

So Where Do We Go From Here?

Colonel James K. Greer stated in his article that there was a need for a new operational design construct for the effective planning and execution of future campaigns and operations.²⁶ Thus doctrine must be good at forecasting as opposed to being predictive, (something which if

²³ John A. Lynn, *Battle. A History of Combat and Culture*. (Colorado: Westview Press, 2003), 319.

²⁴ Clinton J. Ancker III, “Doctrine for Asymmetric Warfare,” *Military Review* Vol. 83, Iss. 4 (Jul-Aug 2003): 25. There is some debate over Clausewitz’s ability to interpret war as being non-linear. This aside, there can be no doubt that Jomini believed in universal maxims and a linear problem set. Ancker posits that the current frustration with asymmetric opponents and operations may be nothing more than the product of an Industrial-Age theory attempting to direct Information Age operations.

²⁵ Beyerchen 1992/93, 59-90, gives an excellent insight into the West’s dislike of nonlinearity. Senge also states that our predisposition toward linear thinking is due to our language structure (Senge, 74.)

²⁶ Greer, 26. In the article Greer lists the five options as being current doctrine; systems approach; effects based; destroy-dislocate-disintegrate; and center of gravity to critical variables. He discusses the basics of each one, its associated benefits and drawbacks, but does not offer advice on which is the most beneficial.

one embraces the concept of complex adaptive systems, it can never be).²⁷ Greer presents one idea of this new operational design construct as one that includes the concept of complex systems and chaos theory with which to force the opposing systems into either chaos or equilibrium.²⁸ Within this construct is the concept of Operational Shock. Operational shock aims to affect the enemy commander's will to fight, by expert maneuver throughout his depth. By inducing a feeling of helplessness, the enemy will be forced to either decline battle or be rendered paralyzed when faced with overwhelming competing demands on his forces, and therefore surrender.

As discussed earlier, future operations will be less contiguous in nature, and in general, fought against non-state actors. Within this environment, traditional depth may be hard to find. Large-scale conventional fights may be currently out of vogue, yet this does not mean they will not reoccur. Thus one must not throw the baby out with the bath water. Conventional threats remain, and as such, the US Armed Force must maintain the ability to fight in "conditions of a high low mix - to be ready to tame the big wildcats and not simply the vicious rodents, to be able to fight troops like Iraq's former Republican Guard as well as Taliban, al-Qa'ida militia and terrorists."²⁹ The key to this is predominantly in the realm of doctrine and concepts and not in continually redeveloping one's forces.

²⁷ Ancker, 24.

²⁸ Shimon Naveh is leading the Israeli Defense Force rewrite of their operational art construct in line with complexity and systems thinking, although this is still in embryonic form. Their idea is similar in nature and aims to frame the enemy as a system, which consists of three components: The Rival, Friendly Logistics, and Friendly Command. This provides the context for the operational framing, which consists of two further components: operational effects and operational functions. This then relates to their idea of the effectuation of the operational strike, more in line with the Russian concept as opposed to the Western ideas of raiding. Their notion of strike has three components: injection (force application), disruption (the effect sought), and extraction (withdrawal or redeployment). The aim is to force the enemy force into either equilibrium or chaos, which then facilitates their planning. The genesis for this appears to have come from the Israeli belief that they cannot force a strategic decision, thus they need to manage the situation accordingly.

²⁹ Michael Evans, "From Kadesh to Kandahar: Military Theory and the Future of War," *Naval War College Review* LVI, No. 3 (Summer 2003): 8. Evans continues to insist that there remains a palpable need for the US to maintain a conventional force, and claims on page 12 of this article that "it would be a very serious mistake to dismiss the possibility of interstate conventional war."

Scope, Limitations and Delimitations

The monograph will not develop a new theory, but will aim to expand a current one by using complexity theory within the operational shock model. It will not examine strategic shock.³⁰ The concept of asymmetry, though an interesting topic in itself will not be investigated further. The current Army definition is used where required.³¹ The monograph will consider the development of systems theory, chaos and complexity theory, and the concept of operational shock theory in detail. The monograph will not address the development of operational design.³²

Assumptions

It is assumed that the current linear systems models are inadequate as a means of developing operational shock. This is predicated on the changing operating environment in which the US Army will fight. It is also assumed that both an army and a non-state actor (either a guerilla unit or a terrorist organization) are complex systems.³³

³⁰ This includes shock in a conflict with nuclear exchange.

³¹ The Army defines asymmetry as something that “concerns dissimilarities in organization, equipment, doctrine, capabilities, and values between other armed forces (formally organized or not) and US forces.” Field Manual 3-0 (Department of the Army), 4-31 (4-109).

³² A quick refresher can be gained through JP 3-0 or JP 5-0. Concepts such as Center of Gravity, Lines of Operation etcetera will be defined as per the Joint Publications, unless stated otherwise. For further details the reader is referred to Chapters 6 and 7 of Wesley R. Odum’s, “*Conceptual Transformation for the Contemporary Operational Environment*.” Monograph, School of Advanced Military Studies, United States Army Command and General Staff College, Fort Leavenworth, AY 2002/2003.

³³ There are numerous papers on this. The best one, which represents the concepts within a traditional army environment, is Andrew Ilachinski’s “*Land Warfare and Complexity, Part I: Mathematical Background and Technical Sourcebook*.” Alexandria, VA: Center for Naval Analysis, July 1996 (especially pages 16-19) and Madelfia A. Abb’s “*A Living Military System on the Verge of Annihilation*.” Monograph, Advanced School of Military Studies, US Army Command and General Staff College Fort Leavenworth, Kansas, AY 99-00. CARL ADA381925. The one viewing the terrorist network through the complexity lens is Michael F. Beech’s “*Observing Al Qaeda Through The Lens of Complexity Theory: Recommendations For The National Strategy To Defeat Terrorism*.” Student Issue Paper, Center for Strategic Leadership, US Army War College, July 2004. A newspaper article covering the same issues can be found in The Washington Times, 9 December 2003 entitled “Leader of Terror Cell Reveals Data on Command Structure.” This article highlights the loose coupling aspect of the network.

Proposed Research Question And Methodology

The proposed research question is “Can complexity theory add to our understanding of Operational Shock Theory to better suit it for full range operations?” The primary research question is can the principles of complexity theory aid in the development of operational shock theory. The secondary research questions include the following; what is operational shock theory, what does it look like when applied to a system, how can it be measured; what are the principles of complexity theory, and what are the relationships between these? Also what principles of complexity theory apply to operational shock theory; what is the idea of complex emergence and what does it offer as an opportunity to the planner; and how does it relate to war termination? The tertiary research questions include the following; what does complexity theory offer the theorist operational planner when trying to impose operational shock, and can an insurgency be shocked?

Methodology

Chapter 2 will answer the secondary research questions. Chapter 3 will examine the issues of how one examines operational shock theory in accordance with chaos and complexity theory to cope with the future environment. This will answer the tertiary questions. The model presented is based the fusing of systems, chaos and complexity theory in order to form a general systems approach to operational shock which will answer the primary research question. An application of complexity theory to the concept of a center of gravity is in Appendix II.

Common Terms

The plethora of terms that exist within chaos and complexity theory are described in Appendix I.

Literature Review

Simplicity achieved by idealized isolation of systems and of variables within systems, deterministic laws, clearly delineated boundaries, linear causal chains, and other tools with which to forge analytical prediction have become the hallmarks of a good theory. By using such techniques, rooted in the parsimonious and deductive power of logic, we have searched for – and therefore overwhelmingly found – static equilibria, constant explanations, periodic regularities, and the beauty of symmetry.³⁴

The purpose of the literature review is to outline the primary and secondary source material used to research the answer to the primary research question, and supporting secondary and tertiary questions. It is necessarily lengthy to ensure understanding.

What Wins At The Operational Level Of War?

Students of warfare have long searched for the panacea that would ensure success, and complexity theory may be the latest Holy Grail. The discovery of the concept of the operational level of war originated in Russia in the 1930s, although the West did not fully understand the implications of this until the mid 1980s.³⁵ Early Western modern statistical studies concentrated on the concept of force ratios and on linking attrition rates to the numerical strengths of the opposing forces, although it was soon apparent that victory was dependent on factors other than force ratios.³⁶ In the 1980s, Dupuy attempted to build a theory of combat that used several other factors other than force ratios. However, as David Rowland states, “it was still force-centred: the additional factors were treated literally as force multipliers, affecting the expected balance of attrition. The final determinant of campaign success was seen as the balance of combat power: the

³⁴ Alan Beyerchen, “Clausewitz, Nonlinearity and the Unpredictability of War.” *International Security* Vol. 17, No. 3 (Winter 1992/93): 86.

³⁵ Shimon Naveh, *Discursive Command – Operators – Systemic Operational Design: A New Framework for Strategic Epistemology* (unpublished thesis n.d.): 2. AirLand Battle appears to very similar to the Soviet concept of operational shock and the deep battle concept.

³⁶ Early investigators in this field include Lanchester (who postulated his square law in 1916), and Helmbold, Willard and Weiss (circa 1960).

sum of the killing power indices of the weapons of each side, times the product of the judged effectiveness indices for all other factors.”³⁷

Later studies, such as those by Speight, Rowland, and Keys tried to analyze advance rates in campaigns (within traditional symmetric constraints) but met with limited success.³⁸ In an attempt to provide data for modeling software, Rowland and Keys proved statistically that the key to operational success consisted of aggressive reconnaissance, control of the air, and creating an environment of surprise and shock within the adversary. These results were however, based exclusively on a sample of battles and campaigns fought in the symmetrical style of the Western Way of War.³⁹ In all of these studies, the disaggregating of campaigns into smaller and smaller constituent parts to allow analysis was still Newtonian reductionism.

Operational Shock Concepts, Paralysis, and Shock and Awe

Concurrent with the search by European and American theorists for a panacea, the Russians developed early operational shock theory in the late 1920s. Russian military officers debated over lessons learned from the Russo-Japanese War, World War I and their own Civil War, and this coupled with an early but immature recognition of systems theory and a dislike for the Clausewitzian decisive battle concept led them to the strategy of exhaustion as opposed to annihilation.⁴⁰

³⁷ David Rowland, L.R. Speight and Michael C. Keys, *Manoeuvre Warfare: Conditions for Success at the Operational Level*. (Unpublished Thesis, Centre for Defence Analysis High Level Studies Department, West Byfleet, UK, n.d.): 1.

³⁸ L. R. Speight, David Rowland, and Michael C. Keys, “Manoeuvre Warfare: Force Balance in Relation to Other Factors and to Operational Success,” *Military Operations Research* Vol. 3 (1997): 42.

³⁹ For a more detailed analysis of these studies see the author’s MMAS. Paul J. Blakesley, “*Shock and Awe: A Widely Misunderstood Effect*” Command and General Staff College, MMAS, Fort Leavenworth, 2003.

⁴⁰ This is a somewhat simplified summary of the debate. Svechin’s recognition of the inability of the Red Army to be able to fight anything but a war of attrition initially, isolated him amongst his contemporary peers. Svechin did state that after the first phase of withdraw and attrition that there would be a second act, that of going onto the offensive after the economy and the populace of Russia had been mobilized. At the other extreme, Tukhachevsky favored an all out offensive based on a fully mechanized army. In the end, it was a combination of the two theorists’ ideas that allowed the Soviet Union to survive.

By recognizing that the weakest point in the realization of war aims was the link between strategy and tactics, the Russians studied how to affect this level of command directly and indirectly. By attacking the operational level of command, it would be possible to prevent the coordinated tactical execution of the strategic plan, and thus deny the enemy his aims. Developing the idea that the operational level of command was mainly a mental construct that acted in a “synapse-like” role, they aimed to create paralysis, or shock, within it. The aim of this operational level “shock” was to create “a consequential state of a fighting system that can no longer accomplish its aims.”⁴¹ The Russians widened the theory by linking this single aim to encompass several successive operations into one single continuous deep operation, and the idea of the deep battle was born.⁴² This continuous operation designed to deal deep and crushing blows, aimed to put whole state organizations out of the game rapidly.⁴³

The effect of the operational shock was to neutralize of the rival system’s rationale for fighting. It would achieve this through an actual attack (and thus was physical in nature), which would lead to a psychological outcome, namely the loss of will to continue fighting.⁴⁴ This will to fight would be removed by a combination of two factors. The first was the changing of the environment (for example by the unexpected arrival of enemy forces on the battlefield at a location which could not be easily countered). The subsequent second factor was the changing of the nature of problem faced by the enemy operational commander. This change was to be sufficient to ensure that the original plans and concepts for battle were unable to attain the aim or

⁴¹ Shimon Naveh, *In Pursuit of Military Excellence: The Evolution of Operational Theory*. (London: Frank Cass, 1997), 16.

⁴² James J. Schneider, “Theoretical Implications of Operation Art,” *Military Review* Vol. 69, No. 1 (January-February 1990): 23.

⁴³ V. K. Triandafillov, *Nature of Operations of Modern Armies*, trans William A. Burhans (Woodbridge, Virginia: 1929), 187. There was even an aspiration that these blows could cause a civil war within in a state, something viewed by the early theorists as the ultimate shock. Triandafillov claimed that this would lead to panic and if the system were shocked sufficiently then “the work of the state began to collapse, panic erupted in locales situated even hundreds of kilometers from the front, the most dangerous internal front began to be organized.” This is clearly a statement referring to civil war.

objectives assigned by the strategic authority. Thus, the concept of operational shock composed of two elements, the strike maneuver and the accompanying systemic shock. It aimed to exploit tensions within the enemy system and through manipulating these cause the system to fall in on itself. This idea thus expressed the *raison d'être* for the operational theory and the concept of the maneuver.⁴⁵

The execution of the strike maneuver usually involved two elements, the horizontal and the vertical envelopment. The horizontal element (predominantly attritional in nature) ensured that individual units in the front would be isolated and hence unable to focus on the larger concepts required of them by the operational level of command. The vertical element played on the hierarchical nature of warfare, by placing a threat far enough into the rear of the enemy to force him to react against what threatened his very force projection capability, though while simultaneously still facing a threat to the front. This maneuver would force the realization of an inability to achieve the strategic aim upon the enemy commander.

In short when focusing on conventional warfare and assuming rational, hierarchical nations or actors, operational shock begins in the rear and works toward the front, and thus is top down in its application. The concept requires several assumptions in order to operate. First, it requires a unified foe with a classical command and control system operating within a nation state environment. This allows the operational effect to achieve strategic outcomes. Second, there must be rationality (or partial rationality) on both sides. While this is generally the case with nation states, this assumption may be invalid in future operations against non-state actors, and thus problematic. Third, it relies on some depth within which a force can maneuver. This depth was plentiful with symmetrical battles, but may need to be adjusted at least conceptually for the future environment. Finally, within the concept of complexity the idea of the shock being imposed from

⁴⁴ This is somewhat simplified. The loss incurred would also include the cohesion and cybernetic functions. Thus, even if the commander desired to continue fighting, the shock would prevent the coordination of this. Regardless of the will to continue, the ability to translate this to action is removed.

the top down violates two basic features of biological phenomena: individuality and locality.⁴⁶ By simply analyzing the effect from the top down, variations within the sub-population are not taken into account.

M. Scott Weaver developed Naveh's thoughts for the asymmetrical battle using cognitive models of thought. He uses a systems approach and argues that Naveh's concepts of hierarchical logic of action no longer exist. He claims that the idea of an operational level of war in asymmetric conflict is useless as the idea of linear and sequential operations collapses into "a snarled chaos involving filaments of simultaneous activity."⁴⁷ Weaver believes that the planning function within the Objective Force should develop Naveh's concepts of the vertical element of a system being its aim and the horizontal as its action while simultaneously attempting to maximize the concept of adaptive dominance.⁴⁸

Dr. James J. Schneider developed the idea of operational shock to account for the information age. By increasing the concept of depth to include the enemy's information age capabilities, paralysis could still be imposed through cybershock, even when the system is aware of its own impending demise.⁴⁹

Paralysis as an idea within US doctrine is not new; both Colonel John Boyd United States Air Force (USAF) and Colonel James Warden USAF advocated it, although they typically concentrated at the strategic level and employed different means.⁵⁰ Boyd stressed the use of simultaneity and depth to affect the enemy's processes and patterns of war, with his theories

⁴⁵ Naveh, xviii.

⁴⁶ Ethan H. Decker, "Self-Organizing Systems: A Tutorial in Complexity," (Available on line at <http://www.ncst.ernet.in/kbcs/vivek/issues/13.1/sos/sos.html>): 2.

⁴⁷ E-mail entitled "Asymmetric Operational Shock," between Paul J Blakesley and M. Scott Weaver dated 12 July 2004.

⁴⁸ M. Scott Weaver "How Many Feathers for the War Bonnet? A Groundwork for Distributing the Planning Function in Objective Force Units of Employment." (Monograph, Advanced School of Military Studies, US Army Command and General Staff College Fort Leavenworth, Kansas, AY 01-02): 22.

⁴⁹ James J. Schneider, "Theoretical Implications of Operational Art," *Military Review* Vol. 69, No. 1 (January-February 1990): 17-27.

⁵⁰ David S. Fadok, "Air Powers Quest for Strategic Paralysis." (Alabama, Faculty of the School of Advanced Air Power Studies Monograph, Maxwell Air Force Base February 1995): 25

rooted in complexity, even if he did not know of the science. The result would render the enemy powerless to react to the ever changing situation; the system would through a process almost identical to cognitive dissonance be forced in on itself and eventually desist.⁵¹

Warden concentrated on the concept of a selected strike designed to decapitate the enemy's strategic leadership, going after what he viewed as the center ring (or key) to his concentric center of gravity (COG) analysis. Only if this was not possible should attacks on the outer rings be conducted to impose pressure inwards. Both theories stress the importance of parallel attack in order to overwhelm the enemy system while seeking to change the environment to such a degree that the enemy system is unable to adapt quickly enough to cope with it and is either forced into equilibrium or chaos.⁵² Issues exist with both, however.⁵³ Boyd's concept was designed for aerial combat, a typically one shot environment, and thus hardly suitable for the operational level. It also stressed the need to constantly out perform one's adversary through "doing," where as it may be that simply being present may be enough. Warden's theory is also snap shot of a system based on an almost perfect information set, and assumes that this snap shot of the COG remains constant. This regresses the theory to linear thinking.⁵⁴ Even more developed work on Warden's ideas has not envisioned the enemy as a complex adaptive system that can deal with set backs and threats.

⁵¹ Both Warden and Boyd's ideas are at heart built from a rejection of linear warfare (and thus the Newtonian paradigm). It may however be too kind to state that they envisaged complexity theory. The idea of Cognitive Dissonance is accredited to Leon Festinger and is at heart that awful feeling one gets when the situation expected is not the situation that turns up. The initial response of most people is to deny reality or try to bend it to fit their preconceived ideas. Once reality is accepted the stress on the mind is directly proportional to the amount of time spent denying the reality. A google search of "When Prophecies Fail" will provide the reader enough of an idea on this topic as opposed to reading his book (although it is a jolly good read).

⁵² The opposite of parallel attack is serial attack, which allows the enemy system to recover and adapt.

⁵³ A critique of Warden's analysis and the development of targeting over the ages of warfare can be found in Peter W. W. Wijninga and Richard Szafranski, "Beyond Utility Targeting: Toward Axiological Air Operations." *Aerospace Power Journal* (Winter 2000): 45-59.

⁵⁴ The US Army has developed Warden's circles by showing them as interlocking Venn diagrams. This model is termed "The Olympic Rings Model." The level of overlap changes with time and the amount of this overlap determine the importance of any one element at that time.

Harlan K. Ullman and James P. Wade harnessed the concepts of Boyd and Warden as well as the technological advancement of precision weapons in their 1996 book *Shock and Awe: Achieving Rapid Dominance*. The aim of “Shock and Awe” (S&A) was through overwhelmingly precise strikes to utterly remove the enemy’s will to resist. The force, acting in accordance with this new doctrine, could leverage its technological advantages and thus reduce its own size, while punching above its weight. This is still attritional and linear at heart, and is little more than the Russian hope of being able to bring about a complete collapse of an enemy state (albeit though without necessarily relying on civil war). Current US doctrine appears to have followed the path laid by Ullman and Wade, citing four components required to achieving shock in a system. They are maneuver (used to concentrate forces to achieve physical and psychological effects), force (applied against decisive points), integration of joint effects (to engage the enemy throughout his depth), and surprise (used to expand again on psychological effect).⁵⁵ All of these concepts however, are maximized for fighting a symmetrical enemy.⁵⁶

In *A Primer in Theory Construction*, Paul D. Reynolds highlights the attributes required to adopt a theory into the scientific body of knowledge.⁵⁷ Within this is the concept of abstractedness, the idea that a concept cannot be bound by its position in time and space, but must be able to predict forward as well as explain historically.⁵⁸ With the predicted change in how the enemies of the US will fight there is a danger that operational design theory (and within it operational shock), if unmodified, will become obsolete. Thus, a nonlinear approach is required. Enter systems and complexity theory.

⁵⁵ FM 3-0, Operations, 4-4, 4-16, 5-12 and Joint Publication 3-0, IV-9.

⁵⁶ Ullman and Wade carefully avoided talking about asymmetric warfare, guerrilla activities or counter-insurgencies. Where they do consider them they state that their concept of Shock and Awe “may prove inapplicable” especially “where the enemy forces [have] relatively few lines to be penetrated or selectively savaged by this type of warfare.” Harlan K. Ullman and James P. Wade, *Shock and Awe: Achieving Rapid Dominance* (Washington D.C: National Defense University, 1996), 4.

⁵⁷ Paul Davidson Reynolds, *A Primer in Theory Construction*, (Boston, Massachusetts: Allyn and Bacon, 1971), 14.

⁵⁸ *Ibid.*, 15.

Systems And Complexity Theory – An Overview

I shall proceed from the simple to the complex. But in war more than any other subject, we must begin by looking at the nature of the whole; for here more than elsewhere the part and the whole must always be thought of together.⁵⁹

General Systems Theory (attributed to the biologist Ludwig von Bertalanffy who advocated an interdisciplinary approach to the study of systems) emerged as scientists realized that a linear approach to real world phenomena was flawed.⁶⁰ Bertalanffy emphasized that systems interacted with their surroundings and thus could adapt to the environment as well as being affected by it. The problem, and the beauty, of systems theory is that it is almost impossible to do just one thing, everything has second and third order effects.

Systems theory has its own plethora of vocabulary, only the essential terms are described here (a comprehensive list is in Appendix I). A system is said to exist when a set of elements are inter-connected so that changes in one element or their relationship with others results in a change elsewhere and the entire system exhibits properties and behaviors different from the parts.⁶¹ The two main types of system are open and closed systems.⁶² Open systems take on board excess energy to replace that which is lost in order to continue operating and remain alive. Closed systems seek equilibrium, and because they are denied the ability to take in energy from outside, in accordance with the second law of thermodynamics, die.⁶³

⁵⁹ Carl Von Clausewitz, *On War*, Edited and translated by Michael Howard and Peter Paret (New Jersey: Princeton University Press, 1984), 75.

⁶⁰ The view of warfare through the Newtonian lens envisages war as predictable as long as we collect perfect information, and through the lens of reductionism, where by we reduce problems to their base constructs to deal with them. Certain elements of the targeting process are good examples of this. Complexity theory offers a broader framework. Newtonian methodologies cannot explain the complex interactions that occur between individuals and groups of systems.

⁶¹ Robert Jervis, "Complex Systems: The Role of Interactions," Edited by David S. Alberts and Tom Czerwinski, *Complexity, Global Politics, and National Security* (Washington D.C.: National Defense University 1997), 1.

⁶² Ludwig von Bertalanffy, *General Systems Theory – Foundations, Development, Applications*. (Eleventh Printing. New York: George Braziller, 1993), 38 and 149.

⁶³ All About Entropy, The Laws of Thermodynamics and Order from Disorder. Available at <http://www.entropylaw.com>. The second law of thermodynamics (the entropy law or law of entropy) was formulated in the middle of the last century by Clausius and Thomson. They based their theory on Carnot's earlier observations that, like the fall or flow of a stream that turns a mill wheel, it is the fall or flow of heat

Systems are also either dynamic or non-dynamic, and linear or nonlinear. A dynamic system will exhibit a change in response over time due to some input, force, information or energy. Within the realm of the dynamic, there are two sub-types of systems, conservative and dissipative. A conservative dynamic system does not lose energy from friction whereas a dissipative dynamic system does.⁶⁴ This friction can be thought of in terms of the amount of energy required to overcome inertia, or that spent on a system's feedback loop mechanism, or simply as the Clausewitzian concept. Finally, any of these systems can be classified as either linear (where they are predictable) or non-linear (where they are non-predictable in the long run).

Systems control themselves through a dual process of feedback and internal models.⁶⁵ Positive feedback reinforces the input to output ratio (for example growth is followed by more growth, reduction by more reduction). This allows change to occur but can result in the system becoming unstable. Conversely negative feedback acts as a braking mechanism, returning the system to equilibrium but leads to a stable system that will approach equilibrium and become predictable and hence die.⁶⁶ Systems that have a preponderance of negative feedback mechanisms

from higher to lower temperatures that motivates a steam engine. This law states that over time there will be an increase in disorder as all things break down from complex composites to their constituent parts. For example, when one burns coal, a simple and singular item, it transforms into heat and light (both of which are forms of energy), smoke, and charcoal or dust (dependent on the temperatures involved). This single piece of coal has broken down into other forms of energy that have dissipated into the atmosphere. Furthermore one cannot take the products after burning and transform them back into coal; the process is irreversible. Thus over time, all systems will breakdown into their constituent parts and the level of disorder, or entropy, will increase. A shorter discussion can be found in Waldrop, 33.

⁶⁴ A dissipative system exists far from equilibrium and efficiently dissipates the heat generated to sustain it and has the potential to develop its level of order.

⁶⁵ The study of the control of systems is called *cybernetics*. The internal models analyze the effects of the decisions and the affects of the environment within which they act to coordinate the next move. An example is a trying to pick an object inside a fish tank up with one's hand while observing through the glass. The internal model (the brain) directs the system (the whole body) to move the hand toward the object. With its depth perception hampered by the change in light refraction, the chances of success on the first attempt are slim. The feedback to the brain is via the eyes, and the brain then adapts its internal model to compensate for the refraction and the process starts again. If there was no internal model then the brain would not be able to analyze the result and the system would be unsuccessful in trying to carry out its actions.

⁶⁶ The term "states of a system" cover these two extremes. The state of a system is a well-defined condition that the system exhibits and can be used to classify it.

are “well-buffered.”⁶⁷ The system makes decisions based on a realization of its actions with the environment, which are captured in its internal models.⁶⁸ Within this internal model is an aim to which the system synchronizes its mechanistic actions towards.⁶⁹ This concept will be covered in more depth in the complexity discussion.

The remaining three issues to understand are variety, fitness and self-organization. Variety will be considered here, the other two within the complexity discussion. Variety is inversely proportional to level of constraint. This level of constraint is determined by examining the difference between the maximum number of states that the system can exhibit and the number of states that can be conceived for that system.⁷⁰ If this number is negative then the system is constrained. Thus the more constrained a system is, the less variety it has, and thus the more predictable it becomes. This leads to Ashby’s law of Requisite Variety that states that only variety can destroy variety.⁷¹ This theory may be crucial in developing future operational concepts. Does sheer size have an effect? Maybe, as if you completely and utterly outnumber the enemy to the point where he cannot do anything to either effect you or adapt to a position of advantage then it

⁶⁷ Dietrich Dörner, *The Logic of Failure – Realizing and Avoiding Error in Complex Situations*. (Translated by Rita and Robert Kimber 1996. Cambridge, Massachusetts: 1989), 75. A well-buffered system incorporates many negative feedback mechanisms and can absorb many shocks and not become unstable. This is both good and bad. By being able to deal with many shocks, the system is unlikely to come apart, but it is also unlikely to embrace change or growth.

⁶⁸ These models are initially simple in nature, but develop over time to allow for complex prediction and learning to occur.

⁶⁹ Naveh, 14.

⁷⁰ A very simple example will explain this. Take a liquid such as water, which can be envisioned to be a gas, a liquid or ice. These three forms which the liquid can be imagined in are also the three states that it can actually be in. Thus, water is not constrained.

⁷¹ W. Ross Ashby, *An Introduction to Cybernetics* (New York: John Wiley & Sons, 1956), 207. The law actually states that the larger the variety of actions available to a control system the larger the variety of perturbations it is able to compensate. Put simply it is easier to predict what some one will do if he can only do a couple of things. The greater their choices the harder it is to predict. If a system can be reduced in its number of options then it can be predicted and thus controlled. This concept has an implication for counter insurgency (COIN) doctrine, as the force deployed to deal with the insurgents must be able to operate at least as flexibly as the insurgents, and ideally with greater flexibility. This will be discussed more in chapter 3 and in the conclusion.

is possible to have forced him to equilibrium, but the causal relationship therein is far from clear.⁷²

This theory has been applied to military systems, where the input is in the form of reinforcements (to enable formations to continue to fight) and information (that enables the staff to change plans accordingly) to deliver the effect required. Their output is in the form of orders and plans for execution by sub-units. With there being limits on resources and the time to receive them, the ability to process information etcetera, the best a deployed military system can hope to be is a semi-open system, destined to finally collapse in on itself. In an attempt to alleviate this, mission command acts as a way of keeping the system partly open. Units cut off from their headquarters can still operate to a certain degree for a period of time. Second, systems theory recognizes that “the ability to survive is programmed into every system” and thus has utility in explaining resistance to shock and the temporal aspect of shock’s effect.⁷³

Why is systems theory so important? First, it recognizes that we cannot expect a threatened enemy system to acknowledge defeat without at first trying to adapt and change.⁷⁴ It also explains why systems strive to continue to operate long after they should have been destroyed. Major Madelfia Abb developed this idea in a monograph entitled *A Living Military System on the Verge of Annihilation*.⁷⁵ Abb shows how living systems have the choice and the ability to change to ensure survival.⁷⁶ She also describes in detail that when a military system is in equilibrium (that is not learning, changing or anticipating) it is combat ineffective and

⁷² The indeterminacy of cause and effect is because size and mass may allow a certain degree of flexibility and that this then equates to variety, or the reverse.

⁷³ Ervin Laszlo, *The Systems View of the World – A Holistic Vision for Our Time* (4th printing. Cresskill, New Jersey: Hampton Press, 1996), 74.

⁷⁴ It is analogous with a boxer, who after being almost knocked out in a round, comes out from his corner having changed his stance to protect his chin from his opponent’s fists; thus his opponent should not anticipate being capable to deliver any single knock out blow using the same tactics as before.

⁷⁵ Madelfia A. Abb, “*A Living Military System on the Verge of Annihilation*.” Monograph, School of Advanced Military Studies, US Army Command and General Staff College Fort Leavenworth, Kansas, AY 99-00.

⁷⁶ Ibid., 17.

therefore “dead.”⁷⁷ Abb also claims that the more an organization is capable of self-organizing and operating far from its equilibrium (that is constantly learning and changing its tactics) the more it is likely to survive.⁷⁸ Abb cites examples from the Second World War and the Korean War where systems that could not adapt to fight their enemy were destroyed.⁷⁹ At the end of the monograph Abb predicts how the theory can be used to help target enemy systems by highlighting three major areas for application:

Isolating or disrupting the functional networks, military structures and cognitive decision making elements of an enemy system that enables living. Destroying or dominating an enemy’s ability to self organize. Force the enemy system to operate toward an equilibrium, making his responses predictive, reactive and limited in number.⁸⁰

Second, systems theory warns us that as war is a non-linear event, no single formula, methodology or capability can predict outcomes or guarantee victory.⁸¹ It also explains why certain inputs, or “shocks” to the system can have disproportionate and unexpected results that change the situation dramatically. Currently the US military doctrine concentrates on attacking things as opposed to systems. Campaign plans are poor attempts at trying to break down a system into its constituent parts and then deal with them individually. In short, despite acknowledging that systems exist, current campaign planning is reductionism at its best. If one subscribes to systems theory, and admits that the world is intrinsically nonlinear, then one must understand the concepts of chaos and complexity.

⁷⁷ Ibid., 31.

⁷⁸ The distance that any system is able to operate from equilibrium is determined by the robustness of its cognitive ability. The greater the level of dissonance that can be tolerated while not preventing the system from working towards its aim the greater the probability of development and emergence.

⁷⁹ Ibid., 44-47.

⁸⁰ Ibid., 48.

⁸¹ Christopher D. Kolenda, “Transforming How We Fight: A Conceptual Approach,” *Naval War College Review* Vol. 56, No. 2 (March 2003): 10.

Complexity

Complexity theory (a relatively new field of research) rose from the twin roots of chaos and systems theory.⁸² Chaos theory, despite its promising beginning, was unable to offer solutions to the majority of problems it highlighted, as well as only applying to a restricted set of phenomena that change in unpredictable ways.⁸³ A more detailed introduction to Chaos Theory is in Appendix I. Complexity theory developed to explain why certain complex adaptive systems that appear to operate close to the realm of chaos are not chaotic and why the second law of thermodynamics did not appear to apply to biology.⁸⁴ As one would expect from its name, the definition of complexity theory has turned out to be hard to find.⁸⁵ In short, it is about the results of interactions that cannot be explained by linear cause and effect. Dörner defines it as “the existence of many inter-related variables in a given system.”⁸⁶ Within this he states that two key of the key attributes of the concept of complexity are those of intransparency and inter-relations.⁸⁷

⁸² For those wanting to discover the development of chaos, systems and complexity theory a good, if somewhat lengthy introduction to these topics can be found in Kevin B. Glenn, “*Complex Targeting: A Complexity-Based Theory of Targeting and Its Application to Radical Islamic Terrorism*,” (Faculty of the School of Advanced Air Power Studies Monograph, Air University, Maxwell Air Force Base, June 2002): 6-44. A more succinct but complicated version is in Andrew Ilachinski’s *Land Warfare and Complexity, Part I: Mathematical Background and Technical Sourcebook*, (Alexandria: Center for Naval Research): 21-23 and 62-63. Complexity Theory is commonly traced back to 1984 and the Santa Fe Institute where elites from differing academic fields began to discuss complex systems in nature.

⁸³ John Horgan, “From Complexity to Perplexity,” *Scientific American* (June 1995): 104-109.

⁸⁴ Through observation, theorists noted that systems did not spin into chaos with monotonous regularity nor did they approach equilibrium and thus stop evolving. It appeared that certain systems were able exist at the edge of chaos and thus by becoming adaptive could attempt to turn the situations they faced to their own advantage and undergo spontaneous self-organization. This forced a switch away from physics and mathematics as a means of explanation, and instead forced an analysis of the dynamism of cell structures. Complexity theory is thus an attempt to explain the behavior of complex adaptive systems. Pure chaotic behavior would preclude any real coordination and evolution over time. This topic is still hotly debated. It is key to point out that any closed system will obey the second law, but biological systems have a highly developed ability to remain, at worst, semi-open in order to survive.

⁸⁵ The problem is not with specific fields of complexity theory where definitions are relatively easy, but with an overarching definition. Perhaps one of the better descriptions is that complexity is a lack of symmetry. Waldrop cites the case where one researcher found 31 definitions of the topic!

⁸⁶ Dörner, 37.

⁸⁷ Intransparency results in an inability to see all of the problem. The interrelation effect results in an action that is meant to affect one part of the system will affect another, thus guaranteeing second and third order effects and subsequent repercussions.

A simple definition would describe a complex system as occurring when “a great many independent agents are interacting with each other in a great many ways.”⁸⁸ Adding depth to this allows the derivation of complexity theory to be the study of systems which exhibit complex, self-organizing behavior. A complex system is any system composed of numerous parts, or agents, each of which must act individually according to their own circumstances and requirements, but which by so acting has global effects which simultaneously change the circumstances and requirements affecting all the other agents.⁸⁹ Thus, the complexity is not brought about by the number of parts within the system but by the interactive and dynamic nature of the system.⁹⁰

Waldrop describes complex systems as having a great number of interacting independent agents, allowing the system to undergo spontaneous self-organization, active adaptation to gain an advantage, and possessing a dynamism compared to static but complex systems.⁹¹ It is an environment where phenomena are unpredictable, but action is within bounds. Thus, complexity falls into two categories: behavioral complexity and system complexity.⁹² Nonlinearity simple put is the absence of linearity. Linear systems exhibit proportionality of cause and effect (twice the input will give twice the output), the idea of additivity (the whole was equal to the sum of the parts), and perfect predictability being possible with perfect information.⁹³ Consequently, nonlinear systems are hard to predict. They respond in differing ways to varying inputs, develop

⁸⁸ M. Mitchell Waldrop, *Complexity The Emerging Science at the Edge of Order and Chaos*. (New York: Touchstone, 1992), 11.

⁸⁹ John F. Schmitt, “Command and (Out of) Control.” (Edited by David S. Alberts and Tom Czerwinski, *Complexity, Global Politics, and National Security*. Washington D.C.: National Defense University 1997), p7.

⁹⁰ Schmitt, 1997: 7, and G. Scott Gormann, “*Adapting to Chaos: American Soldiers in Siberia, 1918-1920*,” (Monograph, Advanced School of Military studies, US Army Command and General Staff College, Fort Leavenworth, Kansas, AY 98-99): 6. A system with a great many parts is described as being structurally complex, or as exhibiting detailed complexity.

⁹¹ Waldrop, 11-13.

⁹² Ilachinski, Part II, 50-61.

⁹³ Czerwinski, Thomas J., *Coping with the Bounds – Speculations On Nonlinearity in Military Affairs*, (Institute for National Strategic Studies, Washington D.C: 1998), 25. This topic was introduced in chapter 1.

their internal models over time and thus can either become extinct or develop rapidly (the concept of punctuated equilibrium). There are four major attributes to nonlinear systems. First, all variables are interdependent; and consequently, everything is interconnected. Reductionism is useless as any action will have second and third order effects. Second, the systems are Sensitive to Initial Conditions (SIC) and so a small change in the initial values can result in a large difference in result. This is identical to chaos theory. Third, the output of the system compared to its input is not proportional. This incorporates the fact that the rule of additivity does not apply (or as is often quoted $2+2 \neq 4$). The collective behavior of a nonlinear system can be greater or lesser than the addition based on the interactions. Finally, nonlinear systems bifurcate into multiple states, as shown in the bifurcation diagram below.⁹⁴

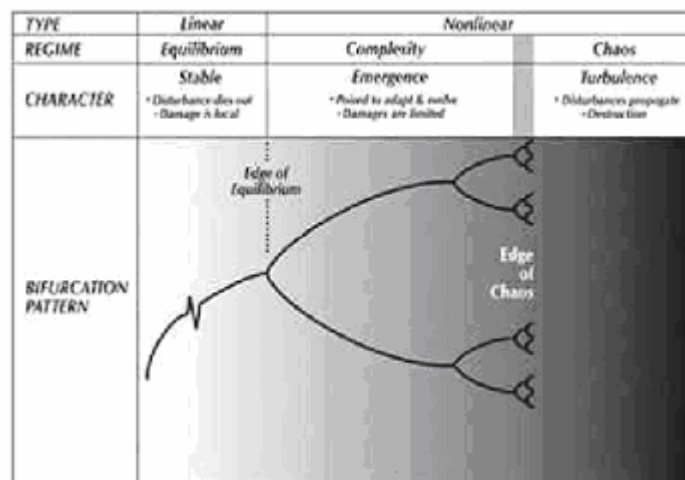


Figure 1: The Bifurcation Diagram – A Graphic Representation Of A System’s Potential Evolution From Equilibrium To Chaos. (Source: Tom Czerwinski, *Coping with the Bounds: Speculations on Nonlinearity in Military Affairs*, 1998), 43.

On the left of the diagram, in the equilibrium zone (characterized by order and linearity), the system is stable without change, innovation, growth, or progress. Existence here implies that regardless of input or disturbance, the system will settle down in a steady state. At the first

⁹⁴ Bifurcation simply means a sudden or drastic change in the pattern or output of a system.

bifurcation, the systems pass the edge of equilibrium and into the complexity zone. This intervening region between chaos and equilibrium (often referred to as the edge of chaos) is the area in which the development of complexity thrives.⁹⁵ It is the point where “life has enough stability to sustain itself and enough creativity to deserve the name of life.”⁹⁶ A perturbation within this zone will force the system to choose between two options and settle down in one of two possible states. A memory of the choice and the possible outcome (built by an internal model) will be stored for future use. Again, if an input (from either the environment or another source) is experienced then the system has to choose again. As one moves further right, the number of states possible double at every bifurcation.

As the system approaches chaos it is forced to make more and more decisions in shorter and shorter time frames and thus cannot calculate for all of the factors, nor recover as quickly from a bad decision. It has become increasingly sensitive to perturbations. Eventually the system will have an infinite number of states to choose from, and thus will never settle down, and therefore is unstable. At this point, the system is pulled into the area where chaos rules, where feedback loops rapidly cause a system to spin out of control, and it is ripped apart.

This however is not the end of the system in its entirety. Unable to operate in a coordinated manner while in chaos it will find itself eventually being pulled toward an attractor which will allow the system to then operate with a semblance of order. Czerwinski further posits that if a system manages to recover after falling into chaos it will reconstitute itself back in the equilibrium realm and attempt to make its way into the complex environment again.⁹⁷ This idea will be developed in the next chapter. Thus as the system moves out from the region of

⁹⁵ Waldrop, 12. The term “the edge of chaos” describes the place where components never quite lock into place, but are not chaotic either. It usually denotes a balance point, although this does not allow for a zone of complexity, and thus should not be seen as such a black and white case.

⁹⁶ Ibid., 12.

⁹⁷ Czerwinski, 51.

equilibrium it begins to develop in complexity. Yet, this gain in complexity forces an increase in disorder. The figure below shows the relationship of this tradeoff.

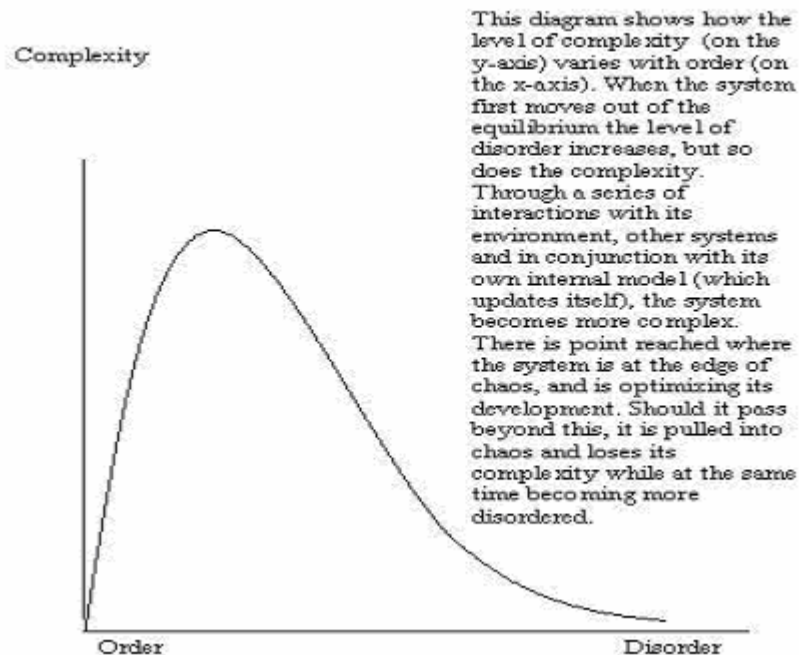


Figure 2: Representation Of The Relationship Between The Level of Disorder and Complexity In A System (Source: Andrew Ilachinski, *Land Warfare and Complexity, Part I: Mathematical Background and Technical Sourcebook* (U) 1996), 73.

The Fitness Landscape Model, Adaptation and Self-Organized Criticality

Most systems, once they enter the complexity domain, desire to interact with both the environment and other systems to become more complex. Not to do so dooms them to either extinction or a return to the equilibrium zone. This development takes place within a fitness landscape, a model based as an abstract of the Darwinian theory of natural selection.⁹⁸ The landscape is portrayed as a multi-dimensional map with the topology representing all the possible states a system can adopt. Systems strive to gain the highest piece of ground within their own

⁹⁸ Charles Darwin, *On the Origin of Species by Means of Natural Selection*. Available on line at <http://www.literature.org/authors/darwin-charles/the-origin-of-species/>.

visual range of this spongy landscape by evolving to take advantage of opportunities. Yet this process costs in energy, and so occasionally sub-optimal solutions may be beneficial. By limiting the amount of visibility, sub-optimal peaks are also possible even with a desire to maximize.⁹⁹ The degree of fitness or success of the organization (system) with a specific option (state) is depicted by the height to which they rise. The guidance mechanics of the system within this landscape is based on the system's continuously updating internal model, which through the results of previous plays as well as predicted outcomes of possible plays, chooses the action, and then interacts with its feedback to select which bifurcation route to take in order to maximize payoffs.

Systems also influence the landscape through their presence. Because all systems are interacting on this spongy surface the shift of one system will deform the landscape and thus create a change in relative position of the others. This can result in the system moving to a lower than optimal point, or having to expend energy to move to another peak. There is also a danger if a system stays in one place too long, out of sight of other systems, that its development vis-à-vis the other systems will slow down.

Conflict can occur naturally as systems continually strive to climb to the peaks and push their competing systems to the troughs. Systems can choose to expend energy on attempting to regain the peak, or on moving to another peak. They can also decide not to act and simply accept a sub-optimal solution. This whole process leads to uncertainty as systems cannot always see each other and thus are operating with less than perfect information. This lack of perfect information also determines the level of interactivity between the systems; when systems can see each other they can interact, when they cannot the interaction is indirect, and hard to measure. The concept of co-evolution (which will be discussed in detail later) originates from this concept.

⁹⁹ One can see that the US Armed Forces desire for perfect information would result in a perfect understanding of this fitness landscape and thus an ability to act in a manner to always maximize one's development at the expense of another (rival's) system.

By the very presence of another system in the same environment as another, they begin to interact, albeit often unknowingly.¹⁰⁰

The fitness of a system determines the probability that the system will survive, reproduce or be produced. This quest for fitness helps explain the development of systems via a feedback mechanism into something that is more effective at surviving. At its simplest, it is evolution and survival of the fittest. It does not rule out less than optimal systems but does predict that over time they will die out. Thus over time systems strive to become more suited to their environments. This includes any competing systems, and explains why enemy systems that are not destroyed on first contact will develop in order to try to survive. The idea of the fitness landscape can be seen in figure 3.¹⁰¹ This links into the concept of a system becoming dominant, that is able to withstand mutations within either a competing system or itself and still remain the one most likely to survive.

Finally, one must understand the idea of adaptive self-organization and self-organizing criticality. Adaptive self-organization is how complex systems instead of tending towards disorder or entropy, spontaneously crystallize into more highly ordered states, but without central control.¹⁰² In other words the “organization of a system spontaneously increases without this increase being controlled by the environment of an encompassing or otherwise external

¹⁰⁰ There is considerable overlap here with the emerging idea of Reflexive Control Theory (RCT). Traditional prediction is an essential component of strategic and operational thinking; many models exist in an attempt to predict the future. The most serious shortcoming of these models is their assumption that the decision-maker is passive. RCT assumes that the decision-maker not only predicts the future but can at least partially affect the future by his own actions. Thus it sees its central problem as developing methods to influence the enemy decision making process by manipulating their perception of reality. This can be done by either affecting the internal model of the CAS or by affecting its feedback mechanisms, or both. The idea is still somewhat in its infancy but shows some promise.

¹⁰¹ An excellent description of this model can be found in Ethan H. Decker, “Self-Organizing Systems: A Tutorial in Complexity” (Available on line at <http://www.ncst.ernet.in/kbcs/vivek/issues/13.1/sos/sos.html>): 8-9.

¹⁰² In its purest form, this is physical existence of the concept of mission command, or the benefit of self-synchronization.

system.”¹⁰³ The key to self-organization is found within the connections and interactions among the part of the system, and thus to ensure that the process continues the system must have a large number of interacting part (or agents).¹⁰⁴

Self-organization originates from the same variation and natural selection processes as the environmentally driven processes of evolution. Therefore, organizations are born, grow, thrive, decay, die and subsequently disappear. All of this takes place as part of the process that also creates, distorts, and dissolves the structures of which they are part.¹⁰⁵ To achieve this self-organizing ability the system must be thermodynamically open, consist of many parts that can interact locally, and be able to benefit from feedback and be capable of emergence.¹⁰⁶

Self-organizing criticality explains how systems drive themselves naturally to the edge of chaos where they maintain themselves indefinitely at a critical state in which complex phenomena appear.¹⁰⁷ This is a dangerous place to exist as a mistake by the internal model may plunge the system into chaos, yet self-organization is less likely the further one moves away from the edge of chaos. Should the system fall into chaos then the remnants of those structures that are ripped apart may be continued in parts of other systems, or may disappear forever. The resilience of a system is partly determined by its self-organizing capability. Akin to the concept of being

¹⁰³ Principia Cybernetica Web. Available at <http://pespmc1.vub.ac.be/complexi.html>. Last accessed 8 August 2004.

¹⁰⁴ Decker, 3.

¹⁰⁵ Ibid., 8. While living system clearly adapt, it is far from obvious that they adapt toward a critical state, unless this movement toward a critical state is necessary to ensure survival. This is one of the key differences between the biological and physical applications of complexity theory.

¹⁰⁶ Ibid., 2.

¹⁰⁷ The use of the word criticality is usually missed out in non-scientific analysis. Criticality within thermodynamics is used in conjunction with phase transitions. At all temperature other than the critical one, any perturbation will only influence the system locally. At the critical temperature then the whole system is affected, although only the closest neighbors to the point of input interact directly. The system has become critical in the sense that all of the members of the system have begun to influence each other. This allows the link to punctuated equilibrium.

well buffered, the resilience of a system is its ability to be able to recuperate from attacks on its constituent parts.¹⁰⁸

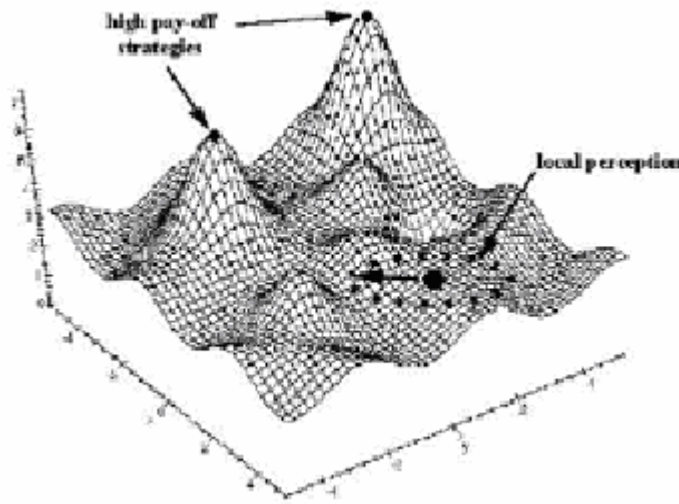


Figure 3: Diagram Illustrating The Concept Of A Fitness Landscape.
(Source: Andrew Ilachinski, *Land Warfare and Complexity, Part I: Mathematical Background and Technical Sourcebook* (U) 1996), 137.

This process often leads to what Czerwinski calls punctuated equilibrium, where periods of self-organizing are normally followed by extended periods of quiet, or put another way a semi-chaotic period is simply an integral part of the whole system.¹⁰⁹ This punctuated equilibrium can be initiated by the interaction of the agents, and thus leads to emergence. Emergence is the concept that the product may not be the sum of the parts and more over cannot be predicted, by either the observer or the agent.¹¹⁰

¹⁰⁸ Michael F. Beech, “*Observing Al Qaeda Through The Lens of Complexity Theory: Recommendations For The National Strategy To Defeat Terrorism.*” (Student Issue Paper, Center for Strategic Leadership, US Army War College, July 2004): 6. Within this paper, Beech examines the concept of coupling as a method for determining the fitness of a system. Tightly coupled systems tend to fall apart quicker than loosely coupled ones.

¹⁰⁹ This is not the same as bifurcation in the true sense of the term. Bifurcations are more common and less likely to result in a system so developing as to render its opponents useless.

¹¹⁰ Emergence is what you get may not be the sum of the parts and cannot be predicted, either by the agent, or us thus with a change in feedback the agent is forced to change and adapt their strategy. At the extreme, the system becomes autopoietic; that is it utilizes elements from it environment to repair itself.

Systems adapt over time to try to take advantage of the changing environment. Nobel Laureate Murray Gell-Mann outlined three levels of adaptation over time that a system uses to react to the changing environment.¹¹¹ The first level, direct adaptation, is typified by the organization reacting to changes in very specific ways, on a very short time scale. The second level is where there is time in responding to events for one adaptation scheme to compete with and replace another. The third level takes place over an extended time-period, and is usually typified by a Darwinian process occurring to implement what the system believes is the best solution. Information processing is essential to the system's ability to adapt.

The core of complexity theory is the Complex Adaptive System (CAS).¹¹² The CAS is dependant on four main characteristics.¹¹³ First it consists of a set of interrelated parts (agents) each capable of acting autonomously if required. Second, the nonlinear interrelationships between these agents make it a system, and third, their ability to break routine to take advantage of the situation makes them complex (simple systems would have simple input and output rules). Finally, their capacity to cope collectively with problems makes them adaptive. As mentioned earlier their interactions and behavior changes the environment making it more hospitable to one system and not to another.¹¹⁴

Despite the lack of a strong central form of leadership, these large collections of agents all interact and operate from the position of being close to equilibrium (but never at it) up to the edge of chaos (though they never fall in through choice). The agents also organize themselves

¹¹¹ Murray Gell-Mann "The Simple and the Complex," (Edited by David S. Alberts and Tom Czerwinski, *Complexity, Global Politics, and National Security*. Washington D.C.: National Defense University 1997), 3.

¹¹² James N. Rosenau, "Complex Systems: The Role of Interactions," (Edited by David S. Alberts and Tom Czerwinski, *Complexity, Global Politics, and National Security*. Washington D.C.: National Defense University 1997), 4. Also in Thomas J. Czerwinski, *Coping with the Bounds – Speculations On Nonlinearity in Military Affairs*. (Institute for National Strategic Studies, Washington D.C: 1998), p13

¹¹³ Czerwinski, 15-20.

¹¹⁴ Robert Jervis "Complexity and Organization Management" (Edited by David S. Alberts and Tom Czerwinski, *Complexity, Global Politics, and National Security*. Washington D.C.: National Defense University 1997), 5. The classic example given is that of Somalia in 1993. The US force, through its deployment, changed the environment in a way that was not envisaged.

into hierarchies. The CAS is further defined by seven attributes, broken down into four properties and three mechanisms. The properties are; aggregation, nonlinearity; flows; and diversity. The mechanisms are; tagging; internal models; and building blocks.¹¹⁵

As discussed earlier spontaneous self-organization allows for massively disorganized structures to crystallize.¹¹⁶ This crystallization would produce new entities or stable aggregate patterns of organization and behavior arising from the interactions of agents. Thus, “a CAS on one level is made of a CAS from a lower level.”¹¹⁷ These groups form, by interaction with other groups, super-groups that again can act as agents, interacting with other agents and so forth, continuing the process. Within this collectivism, however, each part of the hierarchy (be it group or individual) is driven by two opposite tendencies. The first is an integrative tendency, which forces it to act within the larger whole, where as the second is a self-assertive tendency, which encourages the agents and the groups of agents to preserve their individuality. This results in a form of creative tension that can be exploited to reduce the system to component parts.¹¹⁸

The overall behavior of complex systems is self-organized without a centralized agency that dictates what every part ought to be doing, although in the military there is a need for some

¹¹⁵ James K. Greer, “Operational Art for The Objective Force.” *Military Review* Vol. 82, Iss. 5 (September/October 2002): 29. In this article Greer gives an excellent description of the various properties and provides military analogies. Aggregation is the ability of a system to adapt when it encounters problems that are more complex by simply combining smaller systems together (platoons, companies, etcetera). Building blocks are the components of the system that are aggregated to provide new capabilities (units or weapons), or that are produced by the system to allow it to deal with the new challenges. Tagging is the means by which the system identifies itself within the system (Drop Zone (DZ) flashes, colors etcetera). Flows are the movement of information and agents through the system (passing of orders or ammunition). Internal models are self-explanatory (Tactics, Techniques and Procedures (TTP), etcetera). Diversity is the ability of a system to use a variety of agents, models and building blocks to create multiple options for survival (for example the variety of combined arms in battle). Finally, nonlinearity is the means to avoid symmetrical and predictable, and thus open to domination (innovation and out of the box thinking.)

¹¹⁶ This is what could happen in chaos realm once they have been drawn to an attractor.

¹¹⁷ Robert R. Maxfield “Complexity and Organization Management” (Edited by David S. Alberts and Tom Czerwinski, *Complexity, Global Politics, and National Security*. Washington D.C.: National Defense University 1997), 3. Examples of this are the person, the family, the clan, and the firm. Military examples also abound (soldier, squad, platoon, company etcetera). People are members of several CAS at once (person is a member of a family and a soldier).

¹¹⁸ From this description, it is possible to see how armies, guerrilla formations and terrorists fit the description.

central processing. This is the internal model referred to earlier. After the individual sub-agents have interacted while the system may still be the same on the outside in a holistic sense, its internal operating mechanisms will be very different. The new system's stability originates solely from its feedback loops that keep it within a certain tolerable band of complexity.

The CAS exhibits adaptation and co-evolution tendencies, which in the process of evolving and interacting, change and thus change their environment. Even the most complex system can maintain itself in a period of relative stasis before undergoing new adaptive transformations (what complexity theorists call phase transitions.) This punctuated equilibrium is usually followed by a further period exhibiting stable patterns of activity, as the system updates its internal models. Again, this is something that may be taken advantage of by striking quickly after an enemy CAS has undergone a phase change.

Unfortunately in open complex adaptive systems, it is usually impossible to predict when the transitions will occur or what the outcome will be. This means that even when it appears that the enemy is becoming predictable they may morph into something else, *without the other system immediately realizing*. The issue of forcing a phase change by pushing the system into chaos will be covered in chapter 3. The key to the CAS is its ability to process information. This enables the system to realize its position in the fitness landscape, to recognize threats and opportunities and also to be able to analyze the likely results of its actions and the responses both of the environment and potential enemy systems. Thus, two immediate ways to influence a CAS are by either changing its internal model (which is hard) or influencing the feedback to the system. A third way involves taking advantage of the system's desire to replicate success. A CAS, in its attempt to replicate itself, may not take into account recent or current information. This is because

all human predictive models are not linearly regressive in nature.¹¹⁹ This can be used against the system as if it is allowed to reproduce using incorrect or flawed data.

In summary, because of their behavior, CAS cannot be described by reductionist methods. In the act of exploring their properties in isolation, reductionism loses sight of the dynamics. The lifeblood of all complex adaptive systems is the continuous cycling of information from top to bottom to top to bottom.¹²⁰ Unfortunately, complexity theory currently lacks the ability to predict accurately, which planners do not like.¹²¹ There is also a risk of confusion, as one needs to draw from both the study of physics and biology where the concepts of chaos and equilibrium in the two fields are somewhat different. Finally, there is also a risk that complexity theory will fail to deliver all that it promised only a decade ago.¹²²

Yet, from a military planner's view by recognizing the inherent individuality and the fact that both systems (ours and the enemy's) are currently and constantly unfolding highlights a point of focus. Assuming that the enemy's system cannot be chaotic for any long period of time (as this would preclude any real coordination and evolution), but is evolving, it must be operating near the edge of chaos.¹²³ This position however, is one of both strength and weakness. If a tool is developed that will push the system towards stability (and thus away from the zone where evolution occurs), it will force it to be less complex and so easier to deal with in a standard manner. Alternatively, if the planner could force the enemy system into the chaos band it can very quickly be consumed by its own inability to keep up with its changing system.

¹¹⁹ Put simply we allocate more weight to events that have occurred more often in the past to one that has just occurred. Although this does not allow us to predict large changes, it is by far the easiest method of forecasting.

¹²⁰ Andrew Ilachinski. "*Land Warfare and Complexity, Part I: Mathematical Background and Technical Sourcebook*," (Alexandria, VA: Center for Naval Analysis, July 1996), 12.

¹²¹ Horgan, 104-110. Indeed there are still those who think that like Chaos Theory before it, Complexity Theory is unable to deliver on the claims it made to be able to explain a vast number of nature's unanswered questions. Despite this, by identifying the undesirable outcomes for the enemy system, planners can attempt to create conditions through actions that prevent the living enemy system from doing anything except the undesirable choice

¹²² Rosenau, 1.

¹²³ Waldrop, 12.

The above should come with a word of warning, as not only bad things happen in the realm of chaos. In line with the common view that if given an infinite number of monkeys, typewriters and time, that one would produce the complete works of Shakespeare, from the flames of chaos a new phoenix can emerge, more powerful than the last.¹²⁴ Once the system has been pushed into chaos our ability to predict its behavior rapidly diminishes, only long term trend analysis is possible.

Application of Complexity Theory to Operational Shock

We do not know enough about the new sciences to apply them very well yet, but every attempt helps us learn and adapt to the changes with which we must cope.¹²⁵

The goal of force may be not the annihilation or attrition but calibrated elimination of the enemy's resistance.¹²⁶

War is undoubtedly complex. The systems that make up armies (regardless of how they fight) are complex adaptive systems. Thus, there is benefit to be gained from utilizing the model of complexity theory in studying operational shock. This chapter will analyze the current concept through a complexity lens. It will begin by building a model for analysis and then will address the concepts of operational design and shock within the model.

The Basic Model

Initially, for clarity and simplicity, the model built will contain only one entity and will be two dimensional in nature. This will be developed later to allow for more than one system. The model consists of a military system (what makes up this system is discussed in Appendix II), operating within a fitness landscape (as described in chapter 2). The model overleaf represents a

¹²⁴ The aim is not to suggest that Shakespeare was a monkey, but to draw attention to the concept that when one begins to work in the infinite then probabilities of an event occurring at least once tend to unity.

¹²⁵ Alan D. Beyerchen, "Clausewitz, nonlinearity and the importance of imagery" (Edited by David S. Alberts and Tom Czerwinski, *Complexity, Global Politics, and National Security*. Washington D.C.: National Defense University 1997); 168.

¹²⁶ Michael Evans, "From Kadesh to Kandahar: Military Theory and the Future of War," *Naval War College Review* LVI, No. 3 (Summer 2003): 12.

two-dimensional slice through the environment that the system operates within at that one moment in time.¹²⁷ To the extreme left is the zone of equilibrium (where the system is incapable of any productive activity or developing into a more complex state). To the far right is the zone of chaos (where the system either may generate a lot of activity with no purpose or direction, or may simply be wound up in its own destruction). The area in the middle is the complexity zone. Ideally, each system wishes to operate in the center as it offers the most protection from the forces of chaos and equilibrium that can pull it towards them.

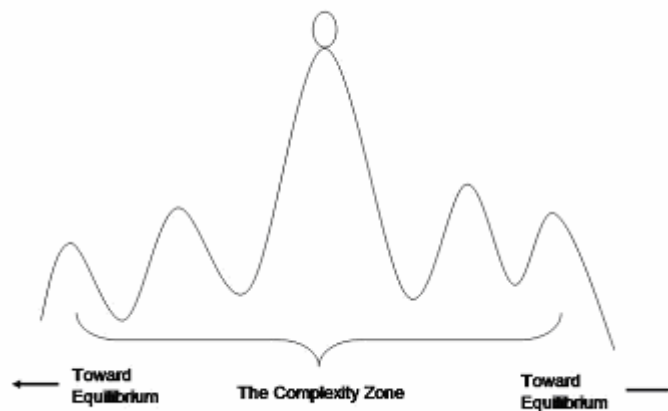


Figure 4: Diagram Showing The Position Of A System In A Fitness

Landscape

In this two-dimensional model, the system constantly searches for the next optimum based on its assessment of the environment and the output from its own internal models. At the center of this is the optimal place for a system to be. The width of the zone is irrelevant. The system is currently maximizing its position in the fitness landscape. This simple system consists of an internal model, a method of viewing the outside world and a means of steering itself on the landscape according to the wishes of its model. Thus the system constantly attempts to remain in

¹²⁷ The symmetrical representation of the fitness landscape is simplistic, but suffices.

the optimal zone and to continue to move down the “complexity trail”, seeking out peaks rather than troughs.¹²⁸

The steering mechanism is based on a combination of the system’s internal model (which develops over time), its ability to gather information on its surroundings, and a willingness to expend energy to move to a new position. The internal model is designed to ensure that the decisions made are optimal based on the amount of information available at the time, and that the feedback received is interpreted accordingly. Within itself the model must also ensure that it develops its own understanding of causality. This model develops with the system, and thus as the system becomes more complex it can interpret more and more data faster and better. The feedback is crucial in allowing the system to assess the results of its action. This feedback will be interpreted by the system’s internal model to work out the causality of its actions and their results, thus providing the internal model with a new set of data points to calculate its position, movement, degree of complexity and opportunities available.

The three essential elements to any feedback and internal model system are intelligence, command and control, and information.¹²⁹ Intelligence provides the initial set to the internal model, based on reports, doctrine and a feeling of likely sets of responses. Once interactions occur, then information provides data for the intelligence system from both the surroundings and the outcomes of actions. The interactions of both of these subsystems allow the internal model to work out its next move and, through the function of command and control, execute its plan.

Finally in this model there is the system’s ability to expend energy, which it can use as it sees fit. Any closed system has a finite amount of energy available to it; an open system is not so constrained. The decision on what the CAS will expend its energy on is a product of both the

¹²⁸ The complexity trail is used to give the impression of a four dimensional world, including the dimension of time.

¹²⁹ G. Scott Gorman, “*Adapting to Chaos: American Soldiers in Siberia, 1918-1920.*” (Monograph, Advanced School of Military Studies, US Army Command and General Staff College, Fort Leavenworth, Kansas, AY 98-99): 11.

internal model and the individual agents. If the CAS is strong then the energy will be expended where it wishes. If the CAS is weak (newly formed from the amalgamation of smaller CAS), or threatened by its proximity to chaos or equilibrium, then the agents' choices may hold more sway. Within the warfare scenario, a CAS may direct energy to four main areas. The first is on moving to another location within the fitness landscape. The second is directing it against an enemy CAS. The third is simply on becoming more complex. The fourth is trying to hold the CAS together when under pressure. The amount of energy entering the system determines the amount that can be expended. The system cannot afford to reduce its energy to zero as here the system will die and break up into constituent parts.

The movement of the system to another position on the fitness landscape cannot happen without an expenditure of energy. Thus, any attempt to move to another point on the fitness landscape must be predicated on a belief that the future position will be better than the current situation. With an open system this is less of a concern as the system can take on energy, but should the system be semi-open or closed then this becomes a greater issue. Finally, there is a need to show the relationship between the expenditure of energy by the system as it moves about the fitness landscape. A simple model is shown below.

The y-axis shows both the force on the system from chaos and equilibrium as well as the amount of force that the CAS expends to remain in the complexity zone. The x-axis shows the distance of the CAS from the optimal position in the zone of complexity. The CAS is always under pressure from the system to be pulled towards equilibrium or chaos. The forces pulling the CAS toward equilibrium and chaos increase as it approaches their respective regions. Through its actions, the CAS expends energy on interactions and forming larger and larger groups to ensure that this state is not reached.

Thus the CAS is never in a position below point a in the diagram. The dotted line represents the force applied by system through its own feedback mechanism to ensure that it stays in the complexity zone. The forces from chaos and equilibrium are shown as the non-linear thick

and continuous line. The further the CAS moves away from the optimal point within the complexity zone the more energy it has to expend to counter the forces pulling it toward equilibrium or chaos.¹³⁰

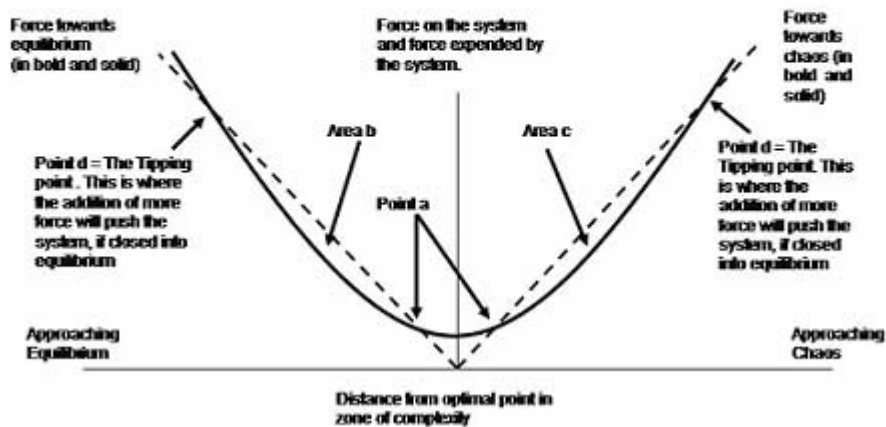


Figure 5: Diagram Showing The Forces Pulling On A System And Its Ability To Employ Elements Of Its Own Power To Counter These.

As long as the CAS can remain within areas b and c it will be able to move itself along the complexity trail efficiently. The closer to point a it remains the more energy it has to concentrate on developing in complexity and updating its internal models. The closer it is to point d the more it must focus on ensuring that it expends its energy toward remaining in the complexity zone.

The CAS's ability to know where it is on this representation is based on its internal model as well as its feedback. Furthermore, the CAS has only a limited amount of energy available to it to resist the forces acting on it. Thus there comes a point (shown as point d), whereby the CAS is

¹³⁰ This representation makes sense. Most people have experience how hard it is to get away from the "but it has always been done this way" mentality as well as the inordinate amount of energy required to

unable to restore its balance and thus will be sucked to one end of the spectrum or the other.

Failures in either the feedback mechanism or the internal model would result in the CAS expending energy in the wrong direction. Specifically, a failure in the feedback mechanism would result in the CAS not being able to tell the result of previous allocation of energy. This would thus force it to continue to expend energy in an inefficient manner, or to accelerate it towards the extremes of chaos or equilibrium. A failure in the internal model would result in the feedback received not being interpreted correctly, and the result would be much the same as that described previously.

The mechanism and the forces shown are relatively simple. The energy available to the CAS is used in several ways. This list consists of the energy the CAS will expend to keep itself within the complexity zone, as well as the energy it will expend on gathering its feedback. It will also include energy spent moving to a perceived optimal point within its fitness landscape and a certain amount of energy directed at its opponents. Thus the CAS is faced with having to allocate a potentially finite amount of energy to resist the move out of the complexity zone, but this draws energy from other activities.

If the system were truly open then it would have an infinite amount of energy available to it.¹³¹ However, systems in conflict are never fully open. As discussed earlier, a military system on deploying from its home base becomes semi-closed. Even a military operating in its own country relies on re-supply etcetera for its continued existence. The only possible exception to this could be a terrorist network that by operating predominantly within the public as it theoretically has a fully open system. Yet despite this they are still constrained by their ability to get weapons and recruits, and rely on the acquiescence of the public to operate and thus may be considered as a semi-closed system as well.

prevent a system approaching chaotic behavior collapsing in on itself.

Thus as a CAS is pulled closer to either equilibrium or chaos it will use its energy more to keep itself within the zone of complexity as opposed to fighting an enemy system. This will be done as the system attempts to adapt and to be able to move to a position where it can gain respite from the forces on it. This is akin to a badly mauled fighting unit withdrawing to a position out of contact to regroup and reform. Given that there is only a fixed amount of force that any CAS can expend, it is faced with stark choices. It can either attempt to change its energy expenditure to counter the forces on it, be ripped apart in chaos or die in equilibrium, or through its own choice, break itself down into the sub-elements of the CAS. However, if it breaks down each part must operate with less complexity. All of these offer opportunity to the planner. It is possible to develop this into the multi-player model, where the actions by the other systems are represented by the addition of forces acting on the CAS. These forces push it either way, either directly through the application of kinetic force, or indirectly via their changing of the fitness landscape.

What are the results of leaving the complexity zone? At first very little. The system will occupy a less than optimal position, which means that it is not developing in complexity.¹³² In a closed environment (not a closed system) this is not problematic, as long as the system was aware of its drift from complexity and had enough energy to spend navigating back to the complexity zone. If the system were unaware of this through either a problem with its feedback, lack of energy or its internal model, then three outcomes are possible. Initially the system may through sheer chance move to continue developing its complexity. This is unlikely to continue for long as the presence of the system in the landscape forces change, and if the internal model is unaware of this then it is more likely that the system will choose a less than optimal path. The second option is that the system, believing itself to be maximizing its development would remain stationary. Again due to the interaction between the system and the landscape, this landscape would begin to

¹³¹ This is not quite true, but will suffice for this model. The counter argument is that the universe in itself is a closed system, and eventually the second law of thermodynamics will increase the amount of entropy.

deform and the system would begin to move away from its optimal position toward either equilibrium or chaos. However, descent into either of these could not occur if the system remained stationary; it would simply sag further and further into the landscape, becoming less fit and thus less likely to be reproduced.¹³³

There is an issue however if the system, through a faulty internal model, or by incorrect feedback chooses to propel itself into either equilibrium or chaos. The move into equilibrium would see more predictable responses and a decrease in complexity of the system. As the system moved towards the equilibrium zone it would be forced to make fewer and fewer choices (it is moving backwards along the bifurcation diagram shown in chapter 2), and be under less pressure. As it gets closer to the equilibrium zone it is possible that the system could split into other less complex systems (that is revert back to its original agents) in order to try and regain an element of complexity. This would only happen, however, if the individual agents were somehow aware of their system's failing model. This is unlikely as the internal model of the larger system is made up from the collective of the agents. If this were not the case the CAS would cease learning and would thus die.

The issue of a move into chaos is more interesting. As the system approaches chaos it is forced to make more decisions in shorter and shorter time scales. Due to the decreased time scale that these decisions have to be made in there is less time for the internal model to analyze the feedback (if indeed any is available). Thus the risk of choosing a sub-optimal path gains in probability. Concurrently the internal model has less time to develop itself and so is more likely to make incorrect decisions. Thus it is more likely that the system's choice of future state will be increasingly less optimal over time. Eventually the system is pulled into chaos and is ripped apart into its constituent parts (or agents). These agents, realizing that they are in chaos will seek out

¹³² This is true for whichever way the system is forced, either toward chaos or equilibrium.

¹³³ In the current model, this would not matter as there is no competition between systems.

attractors as a means of stabilizing themselves. Once they have begun to stabilize, they will then re-emerge into the equilibrium zone, where they react in predictable ways.

What Is Shock In This Model?

Based on this model, an interpretation of operational shock could be when the system's internal model and actual feedback are not in harmony. This is induced through the system's inability to analyze fully its position in time and space as it moves (or executes the decisions of its internal model). When it reaches its desired location there is a risk that through a faulty model, or an interaction with part of the environment that it had not predicted. When this happens the system's internal model suffers a disconnect between perceived and actual reality and potentially can be said to be in a state of shock.

However this is not necessarily paralysis, as the system is faced with a bifurcation point and has a relatively lengthy period in order to orientate itself, work out the causal linkages, readjust its model, and move to a fitness landscape peak. The only way to induce shock in this model is through a constant changing of the environment in between the system's development. Yet the chance of a system being forced into shock by a change in its surrounding alone is somewhat unlikely. There are cases in history where the sudden and dramatic change in the environment resulted in entire species dying off, but they are rare. Furthermore it is unlikely that planners would be able or willing to inflict such a change. Thus the forcing of another system into chaos (or shock) is only likely to be achieved with the presence of another system, and thus needs to be considered within the competitive environment.

The Two Player Competitive Model

The single system model can be developed into one that allows two or more systems to compete within a fitness landscape, although the general concepts explained still apply. For example the enemy system, if fighting away from its own bases will also have become a semi-closed system dependent on supplies, and will continually be in the process of updating its

internal model. Chapter 2 explained how both symmetric and asymmetric players could be represented by a CAS, and thus the topic will not be discussed further here. However, it is important to remember the difference between an open and a closed system. Open systems can take in energy from outside and thus continue to expend energy and become more complex as time progresses. Closed systems will be forced to equilibrium and thus “die.”

When an army remains in its home bases, it is an open system. It can conduct its daily business easily, can plan for future events in a leisurely manner, and is not competing on a fitness landscape with any other hostile system. When an army deploys however, this changes. The system, stretched over a long distance, relies on reinforcements and supplies that are outside of its immediate realm of control. It is also operating in a new theater of operations where its internal model is not fully cognizant with the situation or the cause and effects linkages, and has thus become a semi-closed system.¹³⁴

A semi-closed system is not problematic as long as the system can continue to operate to the level expected without expending its final reserves (be it of logistics or manpower). Should it be forced to expend these then it would become fully closed and will die. Once deployed the internal model will also take time to adapt to the new situation and thus the ability of the system to become more complex is reduced, if only temporarily. Furthermore, once the military system is engaged in any form of operations, its ability to continue to become more complex is hampered. This is because as a system it has no time to take on new methods, or concentrate fully on examining the causal linkages and the internal model of itself and its opponent. This can be problematic as due to Ashby’s law of Requisite Variety control can only be asserted over one system by another system with more variety. As variety is invariably linked to complexity, if one system cannot develop in complexity faster than another, it will soon run the risk of being dominated.

¹³⁴ Even attempts to develop networks with the Host Nation cannot guarantee continuous logistics.

This issue was not a problem with the role of the US Armed Forces within the Cold War environment. Both superpowers' forces would be fighting some distance from home, and thus both would be semi-closed systems. Current expeditionary warfare however has resulted in the US Army deploying for substantial lengths of time in foreign areas. Therefore, the armed forces need time in theater in order to develop their internal models before fighting. These models though are likely to be developed only in terms of understanding the environment; the enemy system unless it chooses to attack will afford little to furnish the model. Training grounds both prior to deployment, and those in theater, allow for some of this to take place but as much as is gained from simply experiencing and operating in the area.

There is the added difficulty that once deployed the force, through its interaction with environment, may change the larger system it finds itself in. The simple actions of the population can be totally different once there are a large amount of troops present. Because of these factors, the US Army CAS needs to expend more energy on simply understanding its surroundings and thus the complexity growth rate is slowed down once the force deploys from its home base. This can be partially addressed by accurate training back in the USA with in depth study of the culture and environment to which the force is deploying as this will help update its internal model. There also exists the diplomatic CAS that can help to set the conditions of the environment (fitness landscape) to posture the US Army for success.

When the two systems find themselves within the same environment, the presence of the system begins to warp the landscape in a manner not expected. This may effect one system more than another may, but it will force both CAS to have to adapt their internal models. This change can be brought about without any direct interaction between the two systems.

What Is Shock In This Model And How Can It Be Imposed?

With systems being able to expend energy on each other both directly and indirectly through the fitness landscape there is a far greater opportunity for one of the systems to be forced into chaos. The issue of forcing a system into equilibrium is harder, but more likely to bring a

longer cessation to conflict at a lower cost than that provided by purely destructive warfare. The precursor to shock is the forcing of the system to expend more energy on remaining in the complexity zone. Two effects bring about this precursor to paralysis.

The first is forcing the system to make more and more decisions as a result of its interaction with both the changing environment and the opposing system but being unable to access the outcome from the previous iteration of moves. Thus in this model shock can be considered the inability of the system to resist being forced towards a phase change. Furthermore, if the phase change is the final stage of the shock, the length of time spent in this new phase state could be considered the degree of awe. The problem as mentioned earlier is that it is possible to keep the system in chaos only if one continues to apply energy and pressure. The moment one relaxes, the system will be able to begin developing its complexity again. Thus to continue to impose shock one must either maintain huge amounts of energy or somehow increase the pressure (for example change the environment) so that the system cannot return to the complexity zone.

The ultimate shock is the forcing of the enemy system into chaos, where the system is no longer capable of acting in a coherent method. The length of time that the system spends in chaos is proportional to the degradation of the CAS into lower CAS. Awe could also be defined as the length of time that after coming out of chaos the system is unable to become complex again.

Any system that realizes what is being done to it can expend energy in one of two ways. It can use its energy to try to affect the other system (to remove the force propelling it towards chaos) or it can also use its energy to try to prevent itself from being pushed into chaos. The latter is a more passive response, and is more likely to be represented by a return to linearity. This linearity is represented by the returning to “what worked last time” mentality and is easier to predict.

How Does One Deal With The System And Impose Shock?

With the recognition of shock within the model identified, it is necessary to identify how to impose this on the enemy. The choices available to the operational planner are few. Although

they wish to destroy the enemy system in its entirety to prevent reoccurrence, this action will not be easy as the self-regulating ability of the complex system imparts a high degree of resiliency. It is also very inefficient as an action. The planner has three options; force the enemy system into chaos; force it into equilibrium; or prevent it developing further. To do this one can either target (that is physically destroy) the whole set of sub systems or by removing the aim or the control mechanisms of the system.¹³⁵

Pushing The System Into Chaos

The issue of forcing the enemy system towards or into chaos will be examined first, although several of the mechanisms identified will have applicability within the three options.¹³⁶ There are two main ways to push the system into chaos. The first is to remove the central model's ability to process information. This can be achieved by direct destruction, or by manipulating the system's internal model processing. The second is to render the system unable to deal with the changing environment.

Analyzing the first, and more direct approach of dealing with the system's internal model, presents three sub-options. The first is by destroying the central leadership. This is essential, not because of the fact that it will cause a result in itself, but in that it directly targets the system's main information processor. Destruction of this key leadership denies the system an ability to navigate the fitness landscape. This does not however result in the system entering chaos, as CAS will develop accordingly and compensate over time for the attrition. It does however reduce the development of complexity of the system, which would create breathing space for the other system. The system, constantly denied an ability to redevelop its internal

¹³⁵ Shimon Naveh, *In Pursuit of Military Excellence: The Evolution of Operational Theory*. (London: Frank Cass 1997), 42.

¹³⁶ That is forcing the system to equilibrium, chaos or preventing it from developing.

model through the constant removal of the new set of leaders or decision-makers, would be rendered inefficient.¹³⁷

It may also force the CAS to disintegrate into its constituent agents, or several less complex CAS. This may be ideal initially, but as time progresses, the planner is left facing several different CAS, each of which may develop differently and thus need to be dealt with in a different manner. Also with reference to Ashby's Law of Requisite Variety, the splitting of one CAS into several increases the risk of greater variety of the enemy, and the subsequent loss of domination by the US forces.

This course of action (COA) however relies on almost perfect information. The best that this action can achieve is an inability for the enemy system to coordinate its actions, which may result in a reduction in attacks. The danger of adopting this COA should be apparent. The removal of the leadership could bring about a sudden change in operating procedure that was not predicted. This step change is similar in nature to the self-organizing criticality that was discussed in chapter 2. By forcing the CAS closer to the edge of chaos it is placed in an environment where change is more likely.

Manipulating the CAS's internal model itself brings about the second sub-option. In order for the system to remain adaptive it must ensure that it benefits from feedback. The three essential elements to any feedback and internal model system were discussed earlier. In short, they are intelligence, command and control, and information.¹³⁸ Manipulation can be achieved by either affecting the models prior beliefs, or by manipulating the feedback forcing a change in the internal model, or exploiting a known reaction therein. These will be examined in order.

¹³⁷ The concept of a decentralized hive mind does not apply. By decentralizing the elements one cannot create the conditions of an efficient internal model unless the elements are connected. If it is possible to split the linkages the hive mind is rendered useless. As an example consider the Internet. When one is connected the amount of knowledge available is phenomenal. Remove the connection and the user is only as good as his or her own mind.

¹³⁸ Gormann, 11.

Each CAS builds its internal model on a series of expectation of how the other systems will operate (as well as how the fitness landscape will change over time). Analyzing past actions and events of the other system develops this model. It is akin to using historical research on an enemy to predict his future course of action. If it is possible to skew the other system's beliefs of how systems will respond, then it is possible to force the enemy to make an incorrect decision or choice when faced with an option.¹³⁹ The enemy CAS will also develop its beliefs from studying the US doctrine, which is readily available on the Internet. This allows future adversaries to build up a picture of how the US will fight. Thus, it is essential that the US remove its doctrine from the Internet unless the US is prepared to operate in a significantly different manner than prescribed by its doctrine.

It is also possible to alter or manipulate feedback in order to confuse or deceive the internal model and force it into chaos.¹⁴⁰ This method can be used either a priori to the event or after an event takes place by either not divulging the correct facts or by issuing false ones. Both aim to lead the enemy's internal model to draw the wrong conclusion from an event and thus update itself incorrectly. This will, over time, allow the internal model to build an incorrect appreciation of causality. Eventually when the enemy system is faced with another CAS that does not operate in the predicted manner it will find itself having to devote more energy to updating its own internal model to try and successfully navigate on the fitness landscape as opposed to attacking.

Finally, there is the issue of exploiting a known reaction causal chain. Having built up enough information on the enemy system it is possible that a US CAS could, through deception

¹³⁹ An example of this is how the majority of observers (and Iraqi's) though the US would begin Operation Iraqi Freedom (OIF) with an air campaign prior to the launching of ground troops. By realizing that the enemy system expected one the planners managed to cause confusion in the enemy's internal model by operating in an unexpected manner.

¹⁴⁰ Glenn E. James, "*Chaos Theory: The Essentials for Military Applications*," (Department of Advanced Research Paper, Naval War College Paper 10, Newport, RI, 21 February 1995): 71.

or RCT, use a trick to force a reaction from an enemy system.¹⁴¹ This anticipated response is then countered with the actual deployment or COA, thus causing a breakdown in the enemy internal model. The aim of all of these methods above is not self-serving. They aim to cause a breakdown in the internal model of the enemy CAS, which forces it to make incorrect decisions that will force it into chaos where it will be ripped apart.

The second main approach was that of rendering the CAS unable to deal with the changing environment. Two COAs can achieve this. The first is influencing the environment to such an extent that the enemy CAS is unable to focus energy anywhere except on remaining in the complexity zone. The second is by altering the environment to such a degree that the CAS is forced to make decisions in such short succession that it cannot accurately respond.

Chaos occurs when the system has insufficient time to relax and recover before the next event occurs.¹⁴² The first concept behind this COA is loosely based on what is currently referred to as a shaping operation within US doctrine. One way to try to influence this is through attempting to change the fitness landscapes with each phase of the operation. Unfortunately, this can work both for and against the friendly CAS, as recent events in Iraq have shown. Also the causality is not clear; is it the systems and the environment that by acting together cause the change, or is it simply the environment changes and the systems are left struggling to analyze and recognize the change?

The second option is to force the enemy system to have to make decisions on a decreasing time scale, forcing them to act before they realize that a decision is needed, or cannot work out the environment or allow time for correction if a previous sub-optimal policy has been chosen. This concept is akin to the concept of relative adaptiveness over time and is synonymous with Boyd's OODA Loop.

¹⁴¹ This was discussed in chapter 2.

¹⁴² James, 24.

Current views on symmetric operational shock focus on a paralysis of command, brought about by maneuver throughout the enemy's depth to break the will of the commander. This shock was brought about by the combination of an iterative combination of surprise, a certain amount of attrition to produce the selective destruction and a feeling of vulnerability. Complexity theory simply extends this concept to explaining how the enemy's complex adaptive system can be thwarted by ensuring that it is forced into chaos. However, the aim of manipulating the enemy's internal model is of no use on its own. There is a need to ensure that a level of force is applied to force the system to not only react to the changing environment (if its internal models are incorrect it will have to expend energy on updating this) but also on forcing it to expend energy on dealing with the other system.

As time progresses the enemy system will realize that it needs to adapt and thus will reach a point of decision. The decision can be as simple as updating its model, or be more advanced (such as a change of operating procedure to try to best deal with the situation). These points of decision can be considered synonymous with the point of bifurcation. At each bifurcation the system has to make a choice (even if the choice is not to choose). Again forcing a decision on the enemy CAS is irrelevant if the system is given time to analyze the outcome of the event and update itself accordingly. Nevertheless, if enough pressure is placed on the system to force it to have to make several changes in short succession then the chances of the CAS being able to recover and conduct coordinated actions reduce significantly.

Therefore, by pushing the CAS towards bifurcation points will force it to make decisions and by continuing to force it to make decisions without gaining feedback will create a degree of instability, a precursor to shock. Also of note is that if the system does attempt to change each "new" or modified form inevitably in a period of relative vulnerability as it attempts to work out its new operating procedures. This can be exploited to push the system into chaos. Nevertheless, as mentioned earlier this has risk associated with it too, as the system may be ripped apart or may experience a form of punctuated equilibrium and emerge more complex than before.

Issues With Pushing A CAS Into Chaos

While imposing shock in an enemy CAS by sending it into chaos may be desirable in the short term (as any system emerging from chaos will probably find itself back in the equilibrium zone), it has its issues that planners must be aware of. First, chaos theory makes it possible to undo a system but does not tell you what the outcome will be.¹⁴³ Second, unless we are sure that we can apply sufficient energy to the system to force it into chaos by pressuring the system to operate closer to the edge of chaos the risk of self-organized criticality occurring increases. This would result in a step change in the enemy CAS to a totally different state, one that planners did not anticipate.¹⁴⁴ If this occurred, the only option available to the planner would be to continue to apply overwhelming energy. The aim of this would be to try and force self-organizing criticality changes to occur faster than the enemy system can deal with it in an attempt to force the system into chaos.¹⁴⁵ This is not the ideal solution as it tends towards an ever-increasing spiral of applied force.

Finally the planner needs to understand that once the system enters chaos it may self-destruct, but with the concept of attractors, it is theoretically possible that new system(s) will settle around the remnants of these CAS. Once the energy into the enemy's system is removed what is left should gravitate to an attractor. These attractors may be considered predictable, but

¹⁴³ Pat A. Pentland, "Center of Gravity Analysis and Chaos Theory," (Air War College Research Report, Air University, Maxwell Air Force Base, 1993): 13.

¹⁴⁴ Bak P, C Tang and K Wiesenfeld "Self-organized Criticality" *Physical Review* Vol. 38 (1988): 364-374. In this article Bak et al explain the concept using a model of a pile of sand. The sand pile exists on a table in a state of equilibrium. Initially one can add sand to the pile and it will stay on the pyramidal form, changing the gradient of the sides of the pile. Eventually there will come a point when the addition of one extra grain will cause a catastrophic change in the sand pile, it avalanches and forms a new pyramid with different gradients than the one before. Bak et al refer to this as self-organized criticality. In short, it is an idea of a semi-phase transition.

¹⁴⁵ Ethan, H. Decker, "Self Organizing Systems: A Tutorial in Complexity" (Available on line at <http://www.ncst.ernet.in/kbcs/vivek/issues/13.1/sos/sos.html>. Last accessed 8 October 2004): 7. Referring back to the sand metaphor, the only way to deal with this would be to ensure that the rate of application of sand to the pile is quicker than the avalanche. This would ensure that the CAS would remain in a state of constant flux and thus cannot self-organize. However, once the rate is slowed down the system will gain some stability and may begin to self-organize.

because of indeterminacy of chaos this may not be possible.¹⁴⁶ If there is one attractor then it can be dealt with, but if several exist then the system could morph into several different systems, operating in situations that had not been planned for. There is also the danger that if the energy were not sufficient to destroy the system it could emerge further down the complexity trail than the friendly CAS. On the positive side by pushing an enemy CAS close enough to chaos to prevent any self-organizing criticality occurring, it may be possible to effectively deal with what there is left by pure destruction.¹⁴⁷

Pushing The System Into Equilibrium

The opposite option to forcing a system into chaos is that of forcing it into equilibrium. Once the system is in the equilibrium area, it will become linear in its responses. Perhaps more important is the fact that once in equilibrium it is hard for the system to get back into the complexity realm unless assisted by an outside agency.¹⁴⁸ Most of the methods are the same as found in the analysis of forcing the enemy into chaos, but without the risk of forcing self-organizing criticality. This is therefore the safer of the two options, although is the harder to achieve. The key to achieving either of these options is via information. By denying the enemy CAS the information it needs on its environment and the other competing CAS the system is forced into equilibrium where it cannot develop and thus will die.

Schneider shows this by examining the development of armies during the period of WWII and beyond. He claims, using a complexity theory metaphor, that due to the increased passage of information, armies began to liquefy and flow like water.¹⁴⁹ He posits that the method of dealing with them is by “freezing them”, thus denying them the information that they need to

¹⁴⁶ Susan E. Durham, “*Chaos Theory for the Practical Military Mind*,” (Monograph for Air Command and Staff College, 1997 (ADA 394035)): 26. This links to something called the sixth truth in chaos. This truth states that all trajectories of chaotic systems exhibit mixing in phase-space, and so this may not be true. In short the trajectory may come close to a previous state, it will never be identical.

¹⁴⁷ James, 116.

¹⁴⁸ One interesting point here is that the deployment of the US Army to a country could be exactly the outside stimulant that forces a linear and non-complex system to be pushed into the complexity zone.

be able to adjust. This freezing also denies the flowing of energy through the system (for example, the logistics required to continue to operate). The other side of this metaphor holds for the study into forcing the enemy CAS into chaos. By applying energy to the system it would turn them into a gaseous state, whereby they could not control the overwhelming amount of information presented to them, and thus would be incapable of coordinated action. Again though one must note that it is almost impossible to apply enough energy to keep a system in chaos constantly. Thus the system will attempt to self heal by various methods, including pushing down the level of command to a lower level. This is the purpose of mission command.¹⁵⁰

Limiting the Development of the CAS

The third option is to degrade the CAS so that it never develops its potential or becomes more complex. Waldrop identifies the concept found in trade theory of explosive growth, whereby a system reaches a critical mass and suddenly becomes a market leader.¹⁵¹ Therefore if the enemy CAS can be stopped prior to reaching this point of explosive growth (be it either as a whole CAS or as a grouping of smaller CAS), or pushed back prior to this point, the system should not develop. The reason for wanting to do this is linked to Ashby's Law of Requisite Variety. Ashby's law states that control of a system can only be imposed by a system with more variety, which is directly linked to complexity. Furthermore, a semi-open system will become more complex slower than an open system as it has less energy available to it. Thus if the friendly CAS is aware that the enemy CAS is becoming more complex than it then some method to slow this is required. While not dealing directly with the imposition of shock in the enemy CAS it aims to prevent it from developing into something that could not be dealt with.

Again this type of operation could be considered to be shaping in nature; something designed to set the conditions for the system's subsequent shock. One of the essential elements to

¹⁴⁹ Jim J. Schneider "Black Lights: Chaos, Complexity and The Promise of Information Warfare." (*JFQ* Spring 1997, available at http://www.dtic.mil/doctrine/jel/jfq_pubs/07_15.pdf): 25.

¹⁵⁰ *Ibid.*, 28.

the development of a CAS is the passage of information. Agents who utilize the concept of tagging usually do this.¹⁵² Thus by eliminating the tags one is left with a group of individuals who cannot link actions and thus will not develop. This is part of Warden's strategy of destroying the leadership, but it will not run the risk of moving an already formed CAS towards the edge of chaos, where it can become more complex.

The second option is to try to decrease the system's variety. This again can be achieved by destroying the agents, or stopping the flow of information. By doing this one can force the enemy system to become tightly coupled and thus more centrally controlled.¹⁵³ Once this occurs the system becomes more hierarchical and thus is more vulnerable to strikes against the leadership.

Traditional methods have been attritional in nature, or aimed at the leadership, with planners seeing the idea of chaos as the solution to symmetrical battles. They envisaged that once the leadership was destroyed, or at least overwhelmed then the politicians could bargain from a position of advantage. This may no longer be the case. If the enemy's system can adapt quicker or become more complex then it will only be a matter of time before the US is unable to affect it. If this occurs is there any opportunity to deal with the new system? The answer is yes, but only for a short while. After a system changes it has to undergo a phase where it is effectively drawing breath and attempts to update its internal model. This is represented by the move of the system from one maximum on the fitness landscape to another. If it is possible to strike the system as it draws breath then it can be moved away from its optimum and prevented from gaining in complexity.

Issues with the Competitive Model

¹⁵¹ Waldrop, 126. This phenomenon is referred to as being autocatalytic.

¹⁵² Czerwinski, 15.

¹⁵³ The concept of coupling represents the type and number of control mechanisms within a command and control system and examines how resistant to sudden change that these mechanisms are. An example of a tightly coupled system is the control mechanism for a nuclear power plant. The linkages are

A problem may arise when the enemy is fighting within his own territory and in a manner where his system is loosely coupled. An example of this is a group of insurgents or terrorists. While accepting that the insurgent network requires less of a logistic chain than a deployed force it benefits from the inherently better internal model of the environment that it has over the visitor. It is also the ability of the enemy to be able to test the deployed force to observe its actions and thus update its own model. Attacks on constituent parts will not work if the enemy is loosely coupled, as the shock will not transfer across the system and cause disruption as it does with a hierarchical military.

To overload a system requires that it is at least partially open, otherwise it cannot be dealt with. This is not a problem with a symmetric enemy, as they have to open their system in order to survive, or face death through the closing of their own system. The rule applies for the asymmetric enemy as well. The asymmetric enemy system however has the advantage by being able to close his system for an attack (that is, coalesce into a fighting unit) and then reopen it fully after the attack to take in more energy, or reduce himself back to a lower grouping of CAS until required to coalesce again. This would lead to an apparent morphing of the enemy, although it would not actually be so. Planners need to be aware of this.

By using this technique, the enemy would be able to prevent the system from being manipulated during an attack, and thus could only be dealt with in a traditionally destructive manner, aimed at destroying the whole sub-system. Yet in order to survive the system will have to open, and at this point, it becomes vulnerable. The other preventative factor within this enemy COA is that the longer a system spends closed the more of its internal energy it expends and thus unless careful can actually force itself to die. Thus, planners must consider how to keep the enemy system closed or how to force it to break down into the lower elements of the CAS, thus reducing its complexity. In addition, the enemy system can be prevented from coalescing again if

not meant to be broken or interfered with out of sync, and any attempt to do so can result in a meltdown of

the sub CAS agents can be affected either directly by force, or indirectly through the manipulation of information.

Secondly, one must consider the idea of co-evolution. The simple fact that by their interactions the system will change can result in a system gaining an advantage over its opponent. This would result in a difference between perceived and actual reality in the system that applied a force but did not see the commensurate response or effect. Indeed one of the signs that the opposing system is changing is when tried and tested methods do not produce the results hoped for. Thus planners need to be aware that unless the system can be forced into equilibrium identical but later effects may not produce the same results and thus there is a need to constantly change actions if one wants to get continuing response.¹⁵⁴ Every time the rival systems interact with each other for a finite period, and the result is not one where one of the systems is forced into chaos or equilibrium a bifurcation point is reached. In short, both are faced with a choice of how to adapt. Both models learn from this experience and store away the details for use later. As mentioned earlier this learning aspect of the CAS can associate more weight to recent events than to older ones. If this is the case then it can be manipulated. If the enemy CAS associates more weight to older events than newer ones it can be caught out.

What to Expect in a System that it Shocked

By using the model presented earlier, it is possible to note certain characteristics that when exhibited suggest that shock has been, or is shortly to be, introduced in the system. Initially one should observe an inability of the system to control itself at a higher level, and in the symmetric model this is exhibited by paralysis in the enemy's C2. This results in the enemy system from being unable to coordinate his actions and thus the plan will become unhinged. If the energy is continued to be applied to the system and it is pushed into chaos, there will be a switch from a coherent and structured system of responses to unstructured ones, and potentially a

the system. A more military example is the C2 structure of the French Army at the start of World War II.

reduction in complexity of the enemy. If the input of energy cannot be constantly applied, or the pressure on the enemy CAS is not increased, then those more numerous CAS that have survived their time in chaos will condense on attractors, some more advanced on the complexity trail, some less so. This condensing may manifest itself in either more but less audacious (as the CAS is reduced to its constituent parts) or less attacks (more likely), a growth in the number of organizations claiming responsibility for the attacks (indicative of a reduction of the CAS to constituent parts), and potentially less complex attacks. There should also be a recognizable break up of the leadership.

Al Qa'ida could be an example in point. It appears, as a system, to have been reduced to a less complex network, only able to carry out less audacious attacks.¹⁵⁵ This change has been forced by the double pressure on the CAS of changing the environment (through a combination of all elements of national power as well as deploying forces to threaten their operating bases) and direct action on the system by military forces. The combination of these actions initially pushed the system into chaos, and there has been a reduction of the Al Qa'ida CAS into other constituent parts. Unfortunately it appears that there was an inability to keep sufficient pressure on the system. Consequently the system has re-emerged from chaos and attractors have coalesced remnants of other systems (the attractor is probably radical ideology and the tangible aspect is religious activity).¹⁵⁶

This may have resulted in the migration of some of the forces to fighting against the coalition in Iraq. Yet, even here there is evidence that the continued presence of the US and the coalition is having an effect. The enemy, after attempting to force the US CAS to break down (by direct action against the coalition forces) reached a bifurcation point and changed its tactics to

¹⁵⁴ Jervis, 6.

¹⁵⁵ The opposite view to this is that Al Qa'ida is currently plotting their next large attack. Shock is transient in nature however, and thus any reduction in force that allows the system to recover from the edge of chaos is not optimal.

concentrate on hostage taking, the targeting of police, etcetera. This change of tactics is based on a rational realization of payoffs and is thus not indicative of an enemy in chaos.¹⁵⁷ The reason why the insurgents are currently not in shock is that they are not being forced to change their actions on a quick enough basis to be forced into shock, or denied enough information to force them into equilibrium.

This is in part due to a lack of variation on the part of the coalition troops, and an inability to shape the fitness landscape. There is also the fact that over time only the fit networks are reproducing. Thus by definition an operation that does not fully remove the enemy CAS in its entirety will find itself facing a more developed enemy at a later stage. Thus without a nation state model within which the enemy CAS can be controlled by political masters, an undercurrent of violence is to be expected.

Within complexity theory, a drop in the number of attacks should identify the imposition of shock, as the enemy is forced to expend its energy on other issues. Using a mathematical model built separately by both Ivar Peterson and Jonathan Farley the key issue is to not measure the number of casualties or the size of the attack, but the frequency of the occurrence and the modus operandi employed.¹⁵⁸ A reduction in either of these should be indicative of the method used by the planners as working. Furthermore after a period of no action it is essential that the planner observe what the resumed action is like. More complex or daring attacks indicate that

¹⁵⁶ It is important to point out that these are merely speculations by the author, based on assessing current situation through the complexity lens.

¹⁵⁷ Paul J. Blakesley, “*Big Boy’s Games, Big Boy’s Rules: A Game Theoretical Approach to Modeling Terrorism*,” (Masters of Science (Economics) Thesis, Warwick University, England, AY 92-93): 68.

¹⁵⁸ Ivars Peterson, “Splitting Terrorist Cells,” (<http://www.sciencenews.org/articles/20040110/mathtrek.asp>. Accessed 30 August 2004): 2 and Jonathan, D. Farley, “Breaking Al Qaeda cells: A mathematical analysis of counter terrorism operations (A guide for risk assessment and decision making)” *Studies in Conflict and Terrorism* 26 (November-December 2003): 399-411. Between them Farley and Peterson draw a model where the links between the players represent the flows of information that are key to establishing control. By breaking the links, it is possible to break the CAS. They then produce facts to support their hypothesis that Nationalist groups tend to seek a higher number of fatalities where as revolutionaries appear to seek more wounding, and splinter groups are more interested in death count. This may be of use for a US CAS’s internal model.

their previous actions were not successful in dealing with the CAS. A return to simpler attacks, carried out by more splinter groups is a measure of success.

Can Insurgencies and Terrorist Cells Be Shocked?

Insurgencies and Terrorist cells can be viewed as different levels on the same scale. The terrorist and the insurgent seek the overthrow of a regime, it is simply the level of overt activity that varies. The stronger a terrorist cell grows the more likely it is to try to begin to show its strength in a more open manner, eventually creating an insurgency. Insurgencies can be the emergent result of a grouping of terrorist organizations. Terrorism can be directed at either an external regime (the attacks on the 11th September 2001 are an example), or an internal one, where as insurgencies rise within a country. Yet both seek some form of political change. Insurgencies are hard to quantify as they can vary in state from low level underlying violence to full scale, coordinated actions. At the lower end they are more likely to be seen as either the work of terrorist cells, or simply criminal acts. As such through the eye of complexity they range from the individual CAS to the high level emergent CAS.

Recent studies have shown that it is possible to have small operationally secure groupings, but it is impossible to have large operationally secure cells without either a state sponsor or some comparable form.¹⁵⁹ Thus unlike conventional hierarchical networks which can benefit from scaling, these networks must forego the benefits of size in order to remain resilient to penetration. Eventually, the insurgents will be forced to complete their attempts at overthrowing a regime by resorting to both political and military actions. This requires the formation of a physical and recognizable entity with which to combat any remaining state supporting actors (for example the Army, police force etcetera). Thus in order to achieve their aims, insurgencies have to transition from the clandestine and small unit action to a more

¹⁵⁹ Email Blakesley/Schneider “FW: Case Study – Terrorist Networks (UNCLASSIFIED)” dated 10 November 2004.

conventional and larger scale formation. The timings of this is crucial, as to transform requires a large number of followers. Transforming too soon may result in them being defeated by conventional forces still loyal, or if it is left too late the group may lose cohesion within its ranks and the authorities gain valuable information on the insurgency, allowing it to be accurately and effectively targeted by conventional forces. Thus within each insurgency lie the keys to its downfall.

Unlike complex organisms, insurgencies act like viruses that in seeking to survive bring about the demise of their host. Furthermore they are capable of mutating into many forms and thus can survive for a long period. In addition, like a viral infection the appearance of symptoms can be either acute or chronic. The virus attacks the very fabric of the body, forcing a response that will either rid the body of the infection, keep the virus in check, or in the worst case result in the death of the host. Governments and states, like the body, have their own methods of dealing with viruses. Moreover, like humans, there are “drugs” that can be taken to combat both the symptoms and the actual cause. The danger arises when the symptoms are dealt with, and not the cause. Viruses on their own however are not capable of achieving the effect that they want without multiplying. However, by doing this, they give the body more exposure to its infection and encourage a response. Thus although insurgencies gain synergy through merging their cells, they also become more vulnerable, as they grow in size, and take on more recruits. The state (or body) becomes more aware of them and can begin to coordinate its response.

Despite their apparent resilience it is possible to shock insurgencies in the manner discussed earlier. The constant monitoring of countries thought to be susceptible to insurgencies by a mixture of US Political Departments and Intelligence Agencies will provide early warning of likely actions. The simple deployment of US forces (either conventional or Special Forces (SF) to conduct Foreign Internal Defense) to a region begins to alter the fitness landscape, forcing the enemy CAS to have to expend energy on remaining in the complexity zone. With the additional

reconnaissance assets that the US can bring to bear it is possible to identify the emergent CAS which can be targeted appropriately to prevent it from forming.

Second, the information to the insurgents can be manipulated to encourage them to transform into larger and more conventional fighting units, which can be dealt by conventional forces. Third, once the insurgency has become to form into a more threatening form, surgical strikes (cued by continuous reconnaissance) prevent the agents from linking up to form a larger CAS. This should remove the emergent behavior, which is the most dangerous. If the insurgency forms, it should be pushed into chaos as soon as possible to reduce it back to its constituent parts, as emergent CAS are at their most vulnerable on their creation. This can be done by a combination of effecting the fitness landscape and by the actions of the deployed US force.

Finally there it is possible to break the systems linkage between its aim and actions by forcing an error in its thought process. Naveh's stated that in line with Bertalanffy's theory that each system had an overarching aim and strove to achieve this by a series of mechanistic actions.¹⁶⁰ Shock was the realization of the system's inability to steer its mechanistic actions towards the strategic goal that it had been allocated. If it is possible to apply enough pressure to the system to force it to make decisions without being able to assess their outcome, or simply to order a purely punitive strike then the system will be in shock. By hitting the system to provoke a response that is not in line with the strategic aim it may be possible to keep the insurgency at the tactical level. While at this level the enemy will be capable of inflicting casualties, they will lack the ability to overthrow the government.

Throughout this chapter, it has been shown that complexity theory has applicability to Operational Shock theory. By the embracing of this new science planners can visualize both the enemy and themselves in a systemic manner. This allows for the theory of operational shock to be more abstract and to transfer into the realm of unconventional warfare. It has also been shown

¹⁶⁰ Naveh, 16.

that when utilizing a non-systemic approach the decision of an insurgency to forego the synergistic benefits brought about by acting as viruses can deny the operational planner the ability to impose shock. Yet the embracing of a systemic approach allows a more holistic approach to be employed.

Conclusions and Areas for Further Research

He that will not apply new remedies must expect new evils, for time is the greatest innovator.¹⁶¹

There can be no doubt that an army is a complex system. The soldier is the basic level building block, and even he is a complex set of systems, all of which self-adapt to achieve their local optimum in their own fitness landscape. Soldiers rarely fight on their own. Their squads, platoons, companies and battalions are created by the combination of similar individuals. Thus each agent forms, through his or her interaction, a higher level CAS. Conflict is thus a complex action fought between at least two co-evolving and competing entities. Faced with several organizations operating in non-linear fashions in an overall system where inputs and outputs cannot be measured exactly, nor predicted accurately, any form of linear analysis is destined to fail. Furthermore, anyone expecting to see linear responses to what is a complex system runs the risk of being constantly confounded and unable to act accordingly.¹⁶² One of the great surprises to emerge from studies of nonlinear dynamics has been the discovery that stable states are the exception rather than the rule.

It is possible to destroy a system by a number of means. These include isolating the system (and thus compelling it to equilibrium), eliminating feedback within the system or by applying a huge amount of energy to the whole system.¹⁶³ The first step to control is

¹⁶¹ Sir Francis Bacon. Quote-O-Matic. Available at http://www.srbrowning.com/quotes/index.php?keyword=Francis+Bacon&search_in=1&display=1.

¹⁶² Alan Beyerchen, "Clausewitz, Nonlinearity and the Unpredictability of War." *International Security* Vol. 17, No. 3 (Winter 1992/93): 65.

¹⁶³ Pat A. Pentland, "Center of Gravity Analysis and Chaos Theory," (Air War College Research Report, Air University, Maxwell Air Force Base, 1993): 25.

recognition.¹⁶⁴ Thus it is key that the issues of complexity theory are understood. The second element to control is information. If one can control the information that a system gets then one can break its feedback loop, and thus effect its ability to navigate through the fitness landscape.¹⁶⁵ Any expeditionary army by its very nature of fighting far from home in a hostile country automatically semi-closes its system. This closing of the system will potentially deny the US Army an ability to adapt as quickly as its foes. This is less of a problem if the enemy is fighting in a symmetrical fashion, but if the enemy is fighting asymmetrically then the danger is magnified.

The four major principles of complexity theory (namely self-organization and emergent properties, adaptation or co-evolution, disproportionate effects and sensitivity to initial conditions) accurately describe the future environment. The ability of a system to continue to its journey down the complexity trail, despite the best attempts of the environment and the enemy to prevent it doing so will depend on several factors. The first requirement of any system seeking to deny another (enemy) system its goals is the need to identify the type of system faced. Hierarchical states utilizing their armies in a symmetrical manner can be defeated by a system that targets leadership nodes and is maneuver oriented. There is no real need to dominate the battlefield beyond the period required to force a strategic decision. The current operational design and concept of operational shock is well developed here, and seeks to either place the enemy system in chaos or equilibrium.

This changes when one is facing a more ethereal enemy who is capable of closing his system only when he needs to attack and then can blend back into the population until the next time. By actively targeting the leaders of these organizations they can be thrown into shock (chaos) for a period, which should result in a reduction in the number of attacks. Yet, chaos

¹⁶⁴ Susan E. Durham, “*Chaos Theory for the Practical Military Mind*,” (Research Department the Air Command and Staff School Research Paper, Maxwell Air Force Base, Alabama, March 1997): 30.

¹⁶⁵ Jim J. Schneider “Black Lights: Chaos, Complexity and The Promise of Information Warfare,” (*JFQ* Spring 1997): 22.

theory explains how attractors within chaos soon begin to exert their influence and thus explain the concept of re-emergence of systems thought destroyed.

Thus when faced with this type of system one has three choices. First, to continue to keep the energy input (or pressure rising) to ensure that the chaotic state remains. Second, to destroy the system in one large outpouring of energy. Third, to try to force the system to equilibrium by a manipulation of its feedback so that it renders itself obsolete and becomes extinct. There are issues with each of these. The first solution (maintaining pressure and energy) demands large amounts of attrition. An incorrectly directed expenditure of force could cause second and third order events that change the landscape and thus affect the friendly system. As the amount of force that can be delivered is also not limitless it requires an increase in the pressure on the enemy system to be increased. This is usually the responsibility of other elements of national power as well as coming from other systems operating within the landscape (the populace for example). Consequently for this option to work correctly requires a long-term and multi-disciplinary approach and hinges on factors beyond the direct control of the military. Should one of these fail to maintain the pressure then the enemy system may not be forced into chaos and can continue to evolve.

The second option requires almost perfect intelligence to conduct surgical strikes against all members of the enemy system to ensure that they cannot re-emerge later. A failure in this will leave the enemy system in chaos, but with the beginnings of attractors who can then create a new organization and so the system continues again. The final option, that of forcing the enemy system into equilibrium, while the most desirable as it brings a long-term solution, is by far the hardest to do.

Disorderly behavior offers not only threats but opportunities as well. Systems can be destroyed, forced into extinction or rendered impotent in a less developed manner. However, they can also evolve quickly and turn into something that is far greater than we had hoped for. Ask yourself the question “Has the war in Iraq become an attractor for otherwise chaotic organizations

which have now have condensed and are fighting the US?” It is too early to tell, but an understanding of chaos and complexity theory helps provide some of the answers as to why an insurgency began, and why it is proving so hard to put down.

Answering the Primary Research Question

The monograph asked the primary research question could complexity theory add to the understanding of operational shock theory in full spectrum operations. Complexity lends understanding to the concept of warfare by expanding on the concepts of competing systems. These competing systems are very similar to the models of complex adaptive systems and as such can be influenced by similar influences as their biological brothers. The understanding of complexity theory within operational design (and thus operational shock) leads to the need for changes in current doctrine. The first part to controlling is understanding. Planners must strive to understand the system they face, including its internal model composition, its agents, flows and tagging system. By adopting the complexity model planners will better be able to understand that enemies will adapt over time in response to both their environment and the interaction with other complex adaptive systems.

The Pillars of Behavior Model (in detail in Appendix II) shows how a center of gravity is a complex adaptive and emergent system in itself that will develop over time. The links (or flows) between the three subsystems are shown to be the weakest points, and thus represent an opportunity to attack the system. The model also develops the concept of the Center of Gravity to include the idea of attractors within the realm of chaos (it is to these that the system reverts to when the dynamics dampen). If these condensing points can be identified then the CAS can be pushed into chaos and prevented from returning to either the complexity or the equilibrium zone. If they cannot be identified then the decision to push the system into chaos should be based on a wider analysis of the system. Admittedly, there is more work to be carried out on this model, but its aim was never to be anything more than food for thought.

The secondary questions pertaining to description of theories were answered in chapter 2. Chapter 3 highlighted the linkages between complexity and operational shock. The tertiary questions pertaining to the benefits and hazards of complex emergence with respect to a planner along with what the imposition of shock looked like in a complexity systems model were discussed in chapter 3. The remainder of this chapter will summarize the monograph, and consider recommendations for changes within both current doctrine and organization.

Traditional operational shock aims to overload the commander and ideally, through a series of ever increasing decision points in an ever-decreasing time period, render him unable to control the system, and thus forces it into chaos. This may be ideal with hierarchical structures, where the time bought by the drift of the system into chaos is sufficient to gain a peace on a political level but is unlikely when no such political structure exists. Because of this difference, there is a need to know which sort of system we are facing. If the US faces a symmetric military then the destruction of the key leaders will induce chaos, but this should be enough to influence the next level in the chain of command to sue for peace. If the US is facing an asymmetric enemy the lines blur. If the asymmetric enemy is operating within a nation state the concept of forcing the system into chaos still holds. If the enemy is fighting without a nation state system in place (for example terrorist or guerrillas) then planners need to change their approach. Pushing the system towards chaos may result in the appearance of success as the attacks stop or reduce. If the system is not pushed fully into chaos, when it moves back from the edge it could well be better than it was before the fight.

There are also issues with the measurement of success of imposing operational shock. Traditional operational shock was represented by the inability of the operational commander to deal with the simultaneous threats and by encouraging his political masters to sue for peace. This does not work if no political masters exist, or any form of negotiation is ruled out. As a system is forced towards chaos, it has to make decisions in a quicker and quicker time frame. Each bifurcation point can represent a step change in operating procedure, but this is a poor measure of

success. With each successful change the enemy CAS becomes more complex, and its internal model more advanced. Eventually if allowed to keep changing it will develop to the stage where it can operate in a manner that US forces cannot deal with. Every successful change gives it more experience and hence more variety. Eventually it will out-variant its competitor and thus, in accordance with Ashby's law, can no longer be controlled.

The key is that predicting the long-term future is less important for a complex system to survive than being able to maintain the ability to learn and adapt to a rapidly changing and unpredictable environment. Thus, the planner must aim to deny the enemy CAS this ability while ensuring that the US CAS is allowed to develop. The denial of this to the enemy CAS can be achieved by controlling the environment and operating in new ways. The most important thing is to remain flexible and adaptable.

The Joint Operational Environment recognizes that enemy units will and use the same methods against the US. By attempting to force the US units to make rapid and continuous transitions among types of tactical operations they aim to throw them off balance, disturb coherence, slow and alter decision making, and create windows of vulnerability. The secret may not always be to make them do the same in reverse as it can lead to chaos. However, by forcing rapid changes in configuration designed to reduce the CAS's ability to update its internal model and deny it an ability to continue to develop in complexity, one can create shock. Furthermore, the constant restructuring aims to disrupt the flows between the agents and thus deny them an ability to create meta-agents.

US planners will find themselves somewhat at a disadvantage intelligence wise concerning the likely construct of the enemy CAS's internal model at the start of a conflict. Thus, there needs to be a system whereby the US can build its own knowledge of the likely decisions that the enemy CAS will make. One method of doing so is "pinging." The aim of pinging a

system is to find out what its responses are.¹⁶⁶ Yet, it must not be hit so hard that it is forced either to change, or to propel it into chaos. Either of these results in the system changing and the planner will gain outdated and incorrect information.¹⁶⁷ There is scope within this pinging to engage in deception to influence the enemy CAS. This could be achieved by using a non-standard method of forces to ping the system. The planner gains a response to help build their model whereby at the same time the enemy CAS updates its internal model with an incorrect assumption on how the US will operate in the future. Planners must also expect punctuated equilibriums to occur, even without any pressure from outside. This sudden change in the enemy CAS exposes a short vulnerability as it struggles to understand its new capabilities, something that can be exploited.

As with all theories of warfare, it comes down to forcing the enemy to accept our will. This is achieved by controlling him. The first step to control is recognition. By recognizing that human behavior is complex, and thus anything built on these foundations will be complex in nature, one has begun down the correct road. There are ways of driving a system into chaos or toward equilibrium, and these were covered in chapter 2 and 3. The decision of which to use is crucial, as the outcome is totally different. This choice will depend on many things, but must begin with an understanding of what the enemy CAS looks and behaves like.

One method to control the enemy is through the concept of feedback. However, feedback can be a double-edged sword. If too little is applied the system will not alter its behavior at all. If too much is applied it is possible to induce chaos. Chaos was defined as when the system has insufficient time to relax and recover before the next event occurs which forces another decision.

¹⁶⁶ Glenn E. James, “*Chaos Theory: The Essentials for Military Applications.*” (Department of Advanced Research Paper, Naval War College Paper 10, Newport, RI, 21 February 1995): 118.

¹⁶⁷ This concept is similar to the purpose of the raid when viewed through ex-Soviet Doctrine. The purpose of the raid was purely to disrupt the enemy system and gain knowledge about it to focus future operations in a more surgical manner.

Thus to be able to control the system and ensure that what we do is optimal we need to identify the key parameters within a system and work out which system we are facing and what we wish to do to it. This can be achieved by using the system's internal model based on the pillars of behavior (which are linked to the idea of a Center of Gravity), and use these to influence the system. If it is possible to tweak one to the extent where it forces the system into chaos or equilibrium then you have it beat.

To ensure that the system remains in chaos one must target the likely attractors around which the system will settle once it dampens. The planner again is faced with several options. The destruction of these attractors will stop the system from leaving the zone of chaos, but this COA depends on perfect intelligence. An alternate approach is to leave the attractors (if known) alone as they provide the indicator for where the system will settle on regaining stability. This should ensure that the enemy CAS does not radically alter itself, and thus the planner extends his knowledge of how the system operates. An example of this would see the US not destroying the top enemy leadership, but focussing on the middle leadership. The global trends of operation would remain, although the US would lose some short-term predictability after the initial middle leaders were removed. One of the most interesting factors to emerge from this study into complexity is that systems often function more predictably when not in chaos. Thus, the traditional method of imposing operational shock may no longer be the panacea.

Recommendations for Change

Remaining points of interest will be considered under the headings of Doctrine, Organization, Training, Materiel, Leadership, Personnel and Facilities (DOTMLPF).

Doctrine

US doctrine is open source and readily available on the Internet. Until recently this was also the case with the Center for Army Lesson Learned. Future adversaries will develop their internal models long before they face the deployed US forces. They already see enough of how

the US fights through the media. To reduce the ability of the enemy to update its models on US forces all US doctrine should be removed from the net. Those with access to a computer should be able to access it via a secure log in (at least via Army Knowledge Online (AKO)). This will reduce the enemy's initial advantage.

Shock should become a principle of war. At its very basic level individual shock is what will cause a soldier or insurgent to stop fighting. The doctrine must explain what shock is, how it is imposed and the causal linkages therein.¹⁶⁸ Currently there is no definition of shock within doctrine, nor an explanation of how to impose it. The essential message that must be stressed is that shock is a psychological effect that will act as a combat multiplier beyond all other methods. The key to overwhelming the enemy may well lie in affecting his internal model, either directly or through the feedback, to make him think he is under constant attack and thus has to make decisions without the benefit of analyzing the outcomes of his last ones.

At the operational level, planners need to be reminded through doctrine that no plan ever survives contact with itself, let alone the enemy. The moment a plan is executed it will interact with, and thus change, the environment. Therefore, the planners will have to learn to co-evolve with the environment as opposed to insisting that certain conditions are set before the execution of a phase.¹⁶⁹ The Law of Requisite Variety implies that we need to be more joint and more complex than the enemy. Any viewing of a fight belonging to just one service is doomed to failure.

Doctrine must be more explicit in its recognition of complexity theory. In terms of campaign planning there should be less concentration on synchronization, and more on the concept of the system evolving over time (this links into the intelligence (G2) aspect as well). If

¹⁶⁸ Shock at the individual level is brought about by a combination of surprise, creating a feeling of vulnerability, a rapid approach and a degree of selective destruction. This is covered in more detail in Paul J. Blakesley, "*Shock and Awe: A Widely Misunderstood Effect.*" MMAS Thesis, Army Command and General Staff College, Fort Leavenworth, AY 2003/2004.

total destruction of an enemy system is not possible or not sought, then campaign plans need to have a method of ensuring that when the temporal aspect of their action fades that there is something in place to be able to deal with a possible resurgence of violence. This can be achieved by either forcing extinction or by applying more force, or by accepting a level of underlying violence. The enemy and ourselves are complex, self-adapting systems, and so we must learn to accept a lower level of fidelity. There is a need to update, clarify and where necessary add to the concepts of centers of gravity, phase states, fitness landscapes etcetera. The new “deep” battle should be seen as the shaping of the environment (as opposed to the enemy) from a different perspective; namely one that forces the enemy system to change in line with what we desire. Concepts such as end state should not be seen as a permanently fixed feature of a campaign plan. Should the enemy morph then an original end state may not be achievable.¹⁷⁰

Staff analysis should concentrate more on analyzing the enemy as a system. There is a real need to get the PMESII model into doctrine.¹⁷¹ The sooner people understand that complexity means “many damn things at once” as opposed to a collection of individual linear relationships the better. Within this there is a need to understand that complex systems cannot be studied outside of their environment, the very presence of the US force will change the game. Within the realm of G2 one must consider targeting. An understanding of systems theory should prevent targeting being aimed at the obvious bottlenecks, and will ensure that those seeking an effect understand that the system could well adapt to create a new set of linkages that replace the old (maybe in a better way as well).

Planners need to reevaluate the “divide and conquer” approach to attacking an enemy system. Once the system is viewed in its constituent parts it is no longer an accurate model.

¹⁶⁹ There may be a need to remove the concept of phases from the planning lexicon altogether. This is beyond the scope of this monograph.

¹⁷⁰ This leads to the idea that an end state should be seen within the constraints of a limited time and space window.

Planners also need to consider the implications of a destructive approach. While accepting that a system in chaos is no real system at all, questions such as can the amount of energy be kept within a system to keep it in chaos need to be asked. Concurrent with this, planners need to consider if pushing a system into chaos is the best course of action. The term Center of Gravity should not look at the aspect of will, strength and freedom of maneuver as separate entities, but as a system which can evolve over time and which will combine to produce something that is not predictable from the individual parts.¹⁷²

There is also a need for the lexicon of planners to change. The concept of lines of operation should be changed to lines of effect to allow for a changing environment that will not render the campaign plan irrelevant. Finally, there is also the need to realize that with the ideas of fitness landscape it is possible that there is no optimal solution and thus lengthy *and detailed* rewritten plans are pointless.

Organization

The biggest factor at the organizational level is that the US army must remain adaptive in nature. Unfortunately, this does not always come naturally; history shows that man does not always embrace change.¹⁷³ Furthermore, the adaptiveness must be bottom up led and not top down driven. This has issues with the development of Command and Control (C2) and digitized battlespace control. C2 must be loosely coupled and run at a macro level. This will enable those lower down to adapt to the situation that they are facing as opposed to the one that the higher level headquarters thinks that they are facing – this will increase the level of variety and thus

¹⁷¹ PMESSI is an acronym for Political, Military, Enemy, Social, Structural and Information. The application of the PMESSI and DIME models allow the weaknesses in an enemy system to be exploited by US elements of national power. The PMESSI model is still in a concept phase.

¹⁷² An example may help clarify this point. The large bombing campaign conducted by the Allies over Germany during WWII was designed to break the will of the German people. This did not happen. Perhaps more importantly the system evolved and adapted to harden those areas where it was being subjected to attrition and thus could continue to produce goods.

¹⁷³ The Industrial Revolution and the Luddites are a case in point. The other aspect worth noting is that the industrial revolution was the apogee of linear thinking.

result in out performing the enemy. The idea of constantly increasing one's ability to make timely decisions may not be the answer.

It is essential that the Army's structure remains varied and that all elements conduct training for full spectrum operation. The direction that "Transformation" moves in is essential. The idea of creating special battalions for peacekeeping duties is plausible when one does not expect to deploy them for long periods, or to run out of assets. Should this envisaged environment not be realized however, then they will only be able to operate in a certain manner and thus will have few options open to them. There is a real need to get away from the "I am a branch guy" to the "I am soldier first" (similar to the Marine model). This is addressed in again in the personnel section. The answer to this MOS issue could be to ensure that only a few become real specialists and most become generalists. This would have the effect of getting the majority of soldiers of all ranks back to the coalface to widen their experiences. Agility of a force is a combination of its speed and flexibility. It involves both physical and mental aspects. The physical side is obvious, the mental less so, and thus is discussed within training.

Examining the physical side, it is recommended that the development of the concept of the Unit of Employment (UE) and the employment doctrine of it by the Unit of Action (UA) be continued. This however should be done with all understanding the complexity theory reason behind it. Ashby's law of requisite variety insists that there is a need to have at least as much variety as the enemy to control it. Yet this can be achieved by developing models at the UA that allow complex behavior to develop through the employment of the various UEs. Future operations could be long drawn out events. This favors the opposition. With the US Army's system closing proportionally to the time spent deployed the enemy will hope to have depleted the US to the point where it has little left in variety and thus can be beaten by a conventional force. Thus to prevent this from happening the US Government must ensure that the army remains large enough to go the distance.

In addition, since CAS explain that an enemy can morph into several different forms within a relatively short space of time it is absolutely essential that either the US continues to ensure that it has one of the largest armed forces within the world to ensure that it can out variety the enemy. An alternative to this is to increase the number of types of forces available, and ensure that each of these types has an ability to adapt rapidly to change as well as ensuring a high degree of flexibility therein. This mindset must be spread across all organizations; it is lethal for the majority of the army to see the only solution to the low intensity conflicts as being certain formations (for example the Light Divisions). If the units deployed cannot fight effectively against the enemy then the US will be unable to cannot affect them, except through changes the layout of the fitness landscape, something that is sub-optimal.

Training

Training must continue to emphasize the primacy of humans over machines. Only humans learn effectively and thus they are the essential aspect of any organization. Thus soldiers remain an essential part of the future and over reliance on technology will be a mistake. The human ability to recognize patterns is phenomenal and must never be subsumed to technology. At an individual level soldiers need to have knowledge about the past states of the system and its elements prior to deploying to a theater of operations so that they can continue to monitor likely changes. They will need to understand how changes can forced, and how they can happen without apparent input.

Within this field, there is a continued need for strong interdisciplinary training, which concentrates on developing non-linear intuition and adaptive leaders who are familiar at all levels with the concepts of complexity. Within collective training, scenarios should be allowed to run on regardless of whether or not the unit achieved its specific mission, and the time period of exercises should be increased to allow for the enemy to adapt as well as allowing the exercising troops to change as well. This will force adaptive learning and enable a more complex CAS to develop. Finally, within this section it is important that current modeling and simulation centers

advance their training systems to ensure that complexity is integrated and that modeling does not revert to being aggregated linear functions which are non-evolving in nature. What matters is not being able to predict the future but being able to adapt rapidly to the emergence of new threats.

Materiel

Research and Development must devote more time spend with Effects Based Operations as there is a real need to understand causal linkages. Weapon platforms and communication networks must facilitate the achievement of self-synchronization. Information sharing is the only way forward. Within this it must ensure that certain one-way firewalls exist that prevent senior leaders from meddling or preventing it being screened. This will allow for the development of emergent behavior in US forces. Within the field of equipment production, less money must be spent on creating one large system that claims to be a panacea. What matter where complexity exists is the ability of the lowest level of the CAS to adapt. Building equipment built for one role may allow for a certain depth of specific ability, but it inevitably results in the wrong tool being used in the wrong way or for the wrong job.¹⁷⁴ Basic building blocks will allow the innovative to employ them in new ways, creating an effect that is far greater than their sub optimal use.

Leadership

Complexity theory affects the training of leaders. With the enemy system able to develop its complexity either through interaction with US forces or by punctuated equilibrium leaders must not expect what worked last time to work this time. There is also a need to change the current mindset, which is firepower centric. There is a time and a place for firepower, but it is not the answer every time. The concept is nothing new, but the belief in something that works is.

¹⁷⁴ Max Boot, *The Savage Wars of Peace – Small Wars and The Rise of American Power* (New York: Basic Books, 2002), 331.

Writers from Dörner to Carl von Clausewitz have referred to the desire to use something because it worked last time as “methodism.”¹⁷⁵ As Dörner states,

The “methodist” is not able to cope with specific, individual configurations on their own terms, for he has his two or three ways of proceeding, and he uses one or the other depending on the general features of the situation as a whole. He does not take into account the individuality of the situation as it is evidenced in the specific configuration of its features.¹⁷⁶

Furthermore, Max Boot claims that “many of the expensive weapon systems that the US armed forces have come to rely on are neutralized in small war settings – unless the war in question consists of nothing but punitive strikes.”¹⁷⁷ Leaders must be encouraged to accept greater levels of risk as well as levels of change. They must also recognize that the enemy will change over time. One of the ways to beat a CAS is to ensure that you have more flexibility than it has. This can be achieved by ensuring that control is pushed to the lowest level.

Personnel and Facilities

The personnel structure may have to change on several levels. First, recruiting must strike a balance between numbers and quality. Numbers matter when you need to swamp an area and dominate it, but quality counts when you are involved with a constantly changing environment. The future is more deployment with smaller forces. There can be no room for unthinking soldiers within the lower ranks; it is from these individuals that the CAS that will beat the enemy will

¹⁷⁵ Dietrich Dörner, *The Logic of Failure – Realizing and Avoiding Error in Complex Situations*. (Translated by Rita and Robert Kimber 1996. Cambridge, Massachusetts 1989), 170-171. Dörner describes the effects of “methodism” as being the unthinking application of a sequence of actions learned. He continues his thought to include the concept of individuals becoming deconditionalize to a form of action whereby they use it repeatedly if it has proved successful in the past. He states that Clausewitz observed that ‘so long as no acceptable theory, no intelligent analysis of the conduct of war exists, routine methods will tend to take over even at the highest levels.... War, in its highest forms, is not an infinite mass of minor events, analogous despite their diversities, which can be controlled with greater or lesser effectiveness, depending on the methods applied. War consists rather of single, great, decisive actions, each of which needs to be handled individually....’ Dörner then summarizes Clausewitz’s advice by stating that “In many complex situations, considering a few “characteristic” features of the situation and developing an appropriate course of action in the light of them is not the essential point. Rather, the most important thing is to consider the specific, ‘individual’ configuration of those features and to develop a completely individual sequence of actions appropriate to that configuration.”

¹⁷⁶ Ibid., 170.

¹⁷⁷ Boot, 26.

grow. Second, despite pressure to reduce them, tour lengths must be kept long enough to allow for people to understand the enemy system, but not so long as to become predictable in their actions. Perhaps more importantly, it is critical to not change the whole unit in one go as this would lead to a reduction in the internal model's ability to function and any complexity gained would be lost.

Third, there may be a need to reconsider the current branch specific roles and specialist concept. More benefit will be gained by ensuring that all soldiers and officers gain a wider range of exposure to all forms of operations that currently happens to provide them with a greater understanding of the big picture. Fourth, the US should also continue with its rebasing options. The threat of a conventional war in Europe is negligible and as such, the forces living there are unable to influence the environment elsewhere without deploying. In order to ensure that the US forces do not become a deployed and thus semi-closed system, there is a need to consider rebasing to an area where their presence may alter the environment to the extent where it can prevent the development of a future adversary. This may mean more exotic, but less friendly basing options in the Middle and the Far East.¹⁷⁸

Limitations of CAS and Complexity

Despite all of its promises complexity theory cannot yet anticipate how a CAS will organize itself over time, or how the system will adapt or how it will emerge. It also cannot predict which small inputs will result in large outcomes, nor can it predict punctuated equilibrium. Despite this, however it is a useful tool.

For the disbelievers, conduct this simple experiment. Look out of the nearest window and try to identify a straight line that was not man made. If you are successful examine it more closely as even those man made straight lines are not straight at higher levels of magnification. Examine your vocabulary, when something is running to plan it is operating like clockwork. The language

of planners hinges on the concept of operations, a metaphor for a surgical occurrence, which will result in a return of health. Surgical strikes are those dealt with precision.¹⁷⁹

There is a real need for planners to not only study the non-linear aspects of our world, but also to understand what this actually means. Complexity theory acknowledges the non-linearity of the universe, of life and thus of individuals and organizations. While admitting that organisms are not organizations they provide a close approximation of what should be expected.

Areas For Future Research

Although this monograph answers the primary research question by showing the usefulness of complexity theory within operational design and operational shock there is substantial research yet to be completed. One area is that of developing intelligence and staff analysis procedures to recognize the subsystems of each CAS. Another is continuing investigation into the effectiveness of the UE and UA structure to ensure that suitable conditions for the development of complexity within the friendly system exist. There is also a need to develop the basic model to consider the elements of the CAS's internal model. An attempt at building this is in Appendix II. Finally there is a need to consider how the US can best design its forces to be anti-viral in nature to deal specifically with insurgencies.

Parting Shots

Complexity as a science is still in its infancy. Like its sibling chaos, it may turn out to be nothing more than fools' gold. Perhaps Clausewitz hit the nail on the head when he said

War, however, is not the action of a living force upon a lifeless mass (total nonresistance would be no war at all) but always the collision of two living forces. The ultimate aim of waging war...must be taken as applying to both sides. Once again there is interaction. So

¹⁷⁸ Notwithstanding the political ramifications that these may entail.

¹⁷⁹ John F. Schmitt "Command and (Out of) Control: The Military Implications of Complexity Theory." (Edited by David S. Alberts and Tom Czerwinski, *Complexity, Global Politics, and National Security*. Washington D.C.: National Defense University 1997), 11.

long as I have not overthrown my opponent I am bound to fear he may overthrow me. Thus, I am not in control: he dictates to me as much as I dictate to him.¹⁸⁰

This means one of three things. First, unless we are prepared to deploy the armed forces constantly to deal with threats as they appear, there will be a danger of attacks against the US. Second, regardless of how much energy is expended into a system, unless it is destroyed (which is highly unlikely), or the energy to keep the system in chaos applied continuously, it will eventually re-emerge into the complexity zone and begin to thrive once more. Thus without a way to ensure that the environment is hostile to the enemy it should be expected that forces operating without a traditional military / political chain of command will eventually re-emerge and continue fighting. The concepts of decisive operations and military end states may well be outdated. Finally, once an enemy system is identified, unless it is dealt with quickly and efficiently then it will adapt, learn and morph into a more complex system. This could happen faster than the deployed force is capable of adapting and thus theoretically could result in the defeat of the US force.

In their book *The Anatomy of Military Misfortune*, Eliot Cohen and John Gooch stress that military failures are not the result of individual failures, but stem from the failure of the system to function within its environment.¹⁸¹ The trick is to deny the enemy the ability to act at the time and space of his choosing. Complexity is not all bad news; it offers both opportunity and threats, equally to both sides. What is needed is a warfighting doctrine that aims to overwhelm both mentally and physically, and not by achieving the first by the excessive use of the second. Shock based warfare is the way of the future. Ashby's law abounds everywhere. The more tools the planner has, the greater his variety, and thus the greater his ability to control another CAS.

¹⁸⁰ Carl von Clausewitz, *On War*, edited and translated by Michael Howard and Peter Paret (Princeton: Princeton University Press, 1976), 77.

¹⁸¹ Eliot A. Cohen and John Gooch, *Military Misfortunes: The Anatomy of Failure in War* (New York: The Free Press, 1990), 21-23 and 161-163. Cohen and Gooch identify three major reasons for military failure. These are failure to learn, failure to anticipate and failure to adapt. Within this, they state that the ability to adapt is the most important for any military (94).

The writing on the wall could not be any clearer; understand CAS, or face defeat at the hands of someone who does.

APPENDIX I – Acronyms, Glossary of Common Terms and Concepts

Acronyms

AI	Armored Infantry – this is synonymous with US Mechanized Infantry.
C ²	Command and Control
CAS	Complex Adaptive System(s)
COG	Center of Gravity
COIN	Counter Insurgency
CONUS	Continental United States
CGSC	Command and General Staff College
DGDP	Directorate of Graduate Degree Programs
EBO	Effects Based Operations
FM	Field Manual
GDP	Graduate Degree Programs
HNO	Host Nation Support
HUMINT	Human Intelligence
IO	Information Operations
JFCOM	Joint Forces Command
NSNW	Nonstrategic Nuclear Weapons
RDO	Rapid Decisive Operations
RCT	Reflexive Control Theory
S&A	Shock and Awe
SOF	Special Operations Forces
USA	United States of America
USAF	United States Air Force

Glossary of Common Terms

These definitions have been compiled from the source documents.

Attractor. A region of a dynamical system's state space that the system can enter but cannot leave, and which contains no smaller such region. It is the equilibrium state to which all other states converge on. In linear dynamics it will be a point. In nonlinear dynamics it will be a closed one-dimensional line of points around which the system orbits. This orbit can be in a regular manner or in highly irregular, but still patterned. Non-linear systems have several attractors. Close to the attractor a system will behave chaotically, but once inside the pull it will move predictably towards the attractor. When a system is put under stress the number of attractors tends to increase. When the amount of stress is sufficient to cause an infinite amount of attractors to exist then the system is in chaos.

Autonomous Agents. Autonomous agents are entities that, by sensing and acting upon their environment, try to fulfill a set of goals in a complex, dynamic environment. They can sense the environment through sensors and act on the environment, have an internal information processing and decision-making capability, and they can anticipate future states and possibilities, based on internal models (which are often incomplete and/or incorrect). Since a major component of an agent's environment consists of other agents, agents spend a great deal of their time adapting to the adaptation patterns of other agents.

Bifurcations. A Bifurcation is the splitting into two modes of behavior of a system that previously displayed only one mode. It represents a transformation from one type of behavior into a qualitatively different type of behavior. This splitting occurs as a control parameter is continuously varied.

Chaos theory. The study of non-linear dynamics.

Co-adaptation and co-evolution. Co-adaptation refers to the mutually selective forces acting on entire groups of organisms in an ecology to accumulate favorably interacting genes in the gene pool of the population. Complex systems deal with not just one organism adapting to a given set of circumstances, but with many organisms, all adapting to, and evolving with, all of the organisms that make up their environment.

Constraint. Constraint is the measure of the reduction in variety or reduction of freedom. If the actual variety of states that the system can exhibit is smaller than the variety of states we can potentially conceive then the system is said to be constrained. Mathematically speaking the relationship level of constraint (C) and variety (V) is represented as $C = V_{\max} - V$.

Complexity. Many damn things simultaneously!

Complex System. Any dynamic system composed of many simple, and typically nonlinear, interacting parts.

Complex Adaptive System. A complex system whose parts can evolve and adapt to a changing environment.

Complex Systems Theory. The study of Complex Adaptive Systems

Decentralized Order. Decentralized order refers to the fact that the spontaneous appearance of order in a complex system is typically due solely to parts acting locally on local information. The global order thus emerges without any need for external control. There is no God-like "oracle" dictating what every part ought to be doing.

Equilibrium. There are biological, physical and chemical definitions of this term. In the physical sense an object is at equilibrium when it is at rest. This may be due to the absence of any

forcing acting on it, or the canceling out of two equal, but opposite forces. In chemistry it refers to the balance of the transmission of energy in the sense that if an object is emitting heat at the same rate as the environment can absorb it, the system is said to be in equilibrium. Finally in biology the idea of equilibrium is given to a system that is not developing. For the sake of this monograph a system is said to be in equilibrium when it is in a particularly simple, quiescent state such that its properties are constant and spatially and temporally uniform. The most uninteresting systems, from the point of view of complex systems theory are systems that are in equilibrium. The most interesting systems are those that exist in far-from-equilibrium states, continually seeking new ways to adapt to their environment.

Fitness. Fitness is an assumed property of a system that determines the probability that the system in question will be selected to survive, reproduce or be produced.

Non-linear. In the most basic sense, non-linear means that the output of a system is not directly or inversely proportional to its input. Linear equations contain only addition, subtraction, multiplication or division. Non-linear ones involve logarithms, exponents and trigonometric functions.

Non-periodic. Non-repetitive, and characterized by never settling into a closed loop behavior in phase space.

Phase Space. Phase space is a mathematical space spanned by the parameters that describe a dynamical system's behavior. If the system is described by an ordinary differential flow, the entire phase history is given by a smooth curve in phase space. Each point on this curve represents a particular state of the system at a particular time. For closed systems, no such curve can cross itself. If a phase history of a given system returns to its initial condition in phase space, then the system is periodic and it will cycle through this closed

curve for all time. For example, a mechanical oscillator moving in one-dimension has a two-dimensional phase space spanned by the position and momentum variables.

Reductionism. The practice of analyzing the behavior of an entire system as a product of the behavior of its components.

Self-Organization. Self-organization is a fundamental characteristic of complex systems. It refers to the emergence of macroscopic nonequilibrium organized structures due to the collective interactions of the constituents of a complex system as they react and adapt to their environment.

Self-Organized Criticality. Self-organized criticality (SOC) embodies the idea that dynamical systems with many degrees of freedom naturally self-organize into a critical state in which the same events that brought that critical state into being can occur in all sizes. The kinds of structures SOC seeks to describe the underlying mechanisms for look like equilibrium systems near critical phase-transition points but are not near equilibrium; instead, they continue interacting with their environment, "tuning themselves" to a point at which critical-like behavior appears. Put in the simplest possible terms, SOC is nature's way of driving everything towards a state of maximum complexity.

Sensitivity to Initial Conditions. Sensitivity to Initial Conditions (SIC) explains how deterministic chaos is characterized chiefly by the so-called "Butterfly Effect," which alludes to the fact that two initially nearby points of a chaotic trajectory diverge in time. A small change in an initial condition or parameter results in radically different end states.

State. The collection of dynamical variables at a given time that describe a system.

Systems Theory. The transdisciplinary study of the abstract organization of phenomena, independent of their substance, type or spatial or temporal scale of existence. It investigates both the principles common to all complex entities, and the (usually mathematical) models that can be used to describe them.

Unpredictable Determinism. Sensitivity to initial conditions implies that, despite the dynamics of a system being rigorously deterministic, the long-term behavior of such a system appears irregular and is unpredictable.

Variety. A system's variety measures the number of possible states that the system can exhibit.

Concepts

The table below shows the overlap between research areas, concepts and tools that researchers have found to be useful in describing the properties and behaviors of complex systems.¹⁸² Note the amount of overlap, particularly between the listings appearing under Research Areas and Tools. This underscores the fact that while nonlinear dynamics and complex systems theory have both amassed an impressive arsenal of practical and theoretical tools, these sets of tools are still evolving and are the subject of ongoing research.

¹⁸² Andrew Ilachinski, *Land Warfare and Complexity, Part II: Mathematical Background and Technical Sourcebook*, (Alexandria, VA: Center for Naval Analysis, July 1996): Appendix B.

Table 1: Showing the Linkage between Research Areas, Concepts and Tools. Source - Ilachinski, Andrew. "Land Warfare and Complexity, Part II: Mathematical Background and Technical Sourcebook." Alexandria, VA: Center for Naval Analysis, July 1996.

Research Areas	Concepts	Tools
agent-based simulations	adaptation	agent-based simulations
artificial life	autonomous agents	back propagation
catastrophe theory	autopoiesis	cellular automata
cellular automata	complexity	cellular games
cellular games	computational irreducibility	chaotic control
Chaos	computational universality	entropy
chaotic control theory	criticality	evolutionary programming
complex adaptive systems	dissipative structures	Fuzzy logic
coupled-map lattices	edge-of-chaos	genetic algorithms
discrete dynamical systems	emergence	inductive learning
evolutionary programming	fractals	information theory

The Basics of Chaos Theory

Put simply chaos theory is the study of nonlinear systems.¹⁸³ Chaos theory was “discovered” as early as the turn of the nineteenth century by a physicist, Henri Poincaré. Poincaré found that when using Newtonian physics to predict the movement of the planets that a small variation in the initial input values to the system resulted in a large discrepancy in the

¹⁸³ Linear systems, a product of the Newtonian age, are denoted as sharing three common characteristics. These are proportionality (changes in input lead to proportional change in output); and additivity (the whole is equal to the sum of the parts.) Consequently, even if the linear equation is very complicated, once one knows the inputs one can calculate the output. An excellent, if somewhat long introduction to the topic can be found in Glenn E. James, “*Chaos Theory: Essential for Military Applications*,” Advanced Research Program Paper, Naval War College Newport, RI, AY 94-95. ADA 293163.

predictions.¹⁸⁴ Poincaré examined other systems and was able to prove that for several systems that a tiny imprecision in the initial set variables would grow at an enormous rate.¹⁸⁵ Consequently, prediction was only valid for a short time period.¹⁸⁶ Unfortunately, early interest in the field was minimal and the idea faded.

Chaos theory was rediscovered in the 1960s.¹⁸⁷ Further studies in the 1970s by computers proved that while many systems were highly susceptible to their starting values (sensitive to initial conditions or SIC) and apparently unpredictable in their behavior, they could be modeled in a nonlinear manner. Also discovered was that complicated dynamic systems appeared to have points of instability where a small push could have large consequences.¹⁸⁸

Chaos is an oft-misunderstood term, the term non-linear dynamics is a less loaded and more descriptive term, but is less catchy.¹⁸⁹ Chaotic systems are neither random nor periodic.

¹⁸⁴ Poincaré showed that the motion of three bodies, although each governed by strict and predictable mathematical equations could not be solved as an interacting system using Newtonian Physics. Up to this point, any linear system could be predicted mathematically by using a set of start variables. Once the start set was defined working out positions in the future was simply a matter of mathematical prediction. An explanation of this phenomenon can be found at <http://www.exploratorium.edu/complexity/CompLexicon/chaos.html>.

¹⁸⁵ Lessons in Chaos, University of Texas Website. Available at <http://order.ph.utexas.edu/chaos/index.html>. Accessed 9 August 2004. This web site offers a very user friendly, if somewhat basic, introduction to the theory of chaos.

¹⁸⁶ Prior to this discovery, it had been assumed that any error in the predictive ability of a system was due to an inability to be able to measure accurately the starting variables. In theory, as long as the start values of the variables were measured more accurately the results would be more accurate.

¹⁸⁷ Meteorologist Edward Lorenz, during an attempt to model the weather, developed a software program to try to describe the flow of hot air currents. Despite entering very similar start values for his variables, Lorenz discovered the same results as Poincaré. An infinitesimally small difference in the start values produced drastically different end values. This effect has since become known as the "Butterfly Effect." The idea is that a butterfly flapping its wings could theoretically create enough turbulence in the atmosphere to lead to a storm some time later. The "Butterfly Effect" is often attributed to Lorenz. In a paper in 1963 given to the New York Academy of Sciences he remarked, "One meteorologist remarked that if the theory were correct, one flap of a seagull's wings would be enough to alter the course of the weather forever." By the time of his talk at the December 1972 meeting of the American Association for the Advancement of Science in Washington, D.C. the sea gull had evolved into the more poetic butterfly. The title of his talk was "Predictability: Does the Flap of a Butterfly's Wings in Brazil set off a Tornado in Texas?" This talk is available at http://www.cmp.caltech.edu/~mcc/chaos_new/Lorenz.html.

¹⁸⁸ James Gleick, *Chaos – Making a New Science* (New York: Penguin Books, 1997), 19.

¹⁸⁹ Steven R. Mann, "Chaos Theory and Strategic Thought" *Parameters* Vol. 22, No. 3 (Autumn 1992): 57. The word chaos carries too many images of randomness and anarchy for what is effectively a mathematical discipline. In the article, Mann highlights the use of chaos theory in strategy. A counter argument for the prevalence of chaos in strategy can be found in Colin S. Gray's book *Strategy for Chaos* –

Randomness would result in an inability to predict anything and the best guess for the outcome of the system in the next iteration as being based purely on the last result.¹⁹⁰ Chaotic systems' futures are dependent on their initial conditions. They are not periodic because their behavior never repeats (although it may come close and set a pattern). This is an important point to consider and will be developed later. Despite being relatively unpredictable, these systems can be modeled by equations, and bounded by principles and rules.

The problem with chaotic systems is that they can only be predicted to any degree of accuracy in the very short term. It is possible, however, to estimate how many key variables drive the system and from there begin to attempt to model (and thus potentially control) the system. By analyzing the "attractors" within a chaotic system it is possible to try to ascertain the length of time a system will remain "stable" and thus be predictable. It is also possible to predict how long

Revolutions in Military Affairs and the Evidence of History (University of Reading, Frank Cass & Co Ltd, 2002).

¹⁹⁰ Mathematically speaking this would result in the equation $y_{t+1}=y_t+e_t$. This equation simply states that the output of a system in time $t+1$ would be equal to the value of the system in time t plus an amount of noise (which cannot be predicted) at time t . With this the best guess as to what the system will be at time $t+1$ is t . To try and predict anything else will risk increasing the error. This sheds an interesting light on the idea of lotteries, for if you subscribe to the selection of numbers from a spinning wheel as being totally random syndicates who claim to study form and make predictions on statistical analysis either know something we do not or are missing the point.

a system placed in chaos will take before returning to the complex environment.¹⁹¹ The largest issue with chaos theory is that it has not offered many practical lessons to the military planner except remain agile, flexible, and think on your feet.¹⁹²

¹⁹¹ An attractor is something that the system gravitates towards when in chaos. An example is the natural leader to whom all turn when something catastrophic happens. These attractors could be considered as depressions within an area as they attract the system when it is in chaos.

¹⁹² Michael J. Mazarr, "Chaos Theory and U.S. Military Strategy: A 'Leapfrog' Strategy for U.S. Defense Policy" (Edited by David S. Alberts and Tom Czerwinski, *Complexity, Global Politics, and National Security*. Washington D.C.: National Defense University 1997), 1. In addition to this it can be argued that doctrine should be raised to the correct level, away from Tactics, Techniques and Procedures in order to provide the basic underlying principles. This is outside of the scope of this monograph.

APPENDIX II - The Pillars of Behavior Center of Gravity Model

Current doctrine and operational constructs have concentrated on concrete means and materials that allow fighting to occur and not the essential elements of will or motivation. Yet, motivation on its own is not sufficient. It must interact with the other elements to ensure that it can project its force. Thus there is a need to consider both the CAS approach and the issue of will or motivation.

The Pillars of Behavior Center of Gravity model builds on the concepts of complexity theory studied, and shows how complexity theory is applicable in one part of the field of operational design. Second Generation Warfare sought the destruction of a Center of Gravity as a way of preventing it from influencing the battle. Third Generation Warfare developed this by pursuing an approach of maneuver warfare that rendered it unable to influence the battle. Yet despite its apparent development in concept, maneuver warfare only prevented the Center of Gravity from imposing its force by decoupling the conduits of the implementation of the force, it did not remove its ability to fight. Thus, the Center of Gravity could always resume its functions once it had the force decoupling it removed.

It would appear that current doctrine does not see the Center of Gravity as a system.¹⁹³ There is also confusion among students and scholars alike about what exactly a COG is.¹⁹⁴ By understanding the elements of CAS, the Center of Gravity can be represented as a three way process that of human behavior.¹⁹⁵ Social psychologists have postulated that human behavior comes from the interaction of three major components exhibited by a system that wishes to attack a US force. They are motivation or will, capability and opportunity. Motivation consists of

¹⁹³ JP3-0 describes a Center of Gravity as “Those characteristics, capabilities, or sources of power from which a military force derives its freedom of action, physical strength, or will to fight.” (JP 3-0, Chapter III, 22). In this model, the idea of capability mimics strength, motivation mimics will and opportunity mimics freedom of maneuver. The FM appears to suggest that the COG is not a system.

¹⁹⁴ This is obvious from the plethora of monographs, MMAS and articles written about the topic.

desires, ends, aims, goals, objectives, strategy, and desired end states. Capability consists of the physical aspects (something that warfare has traditionally centered on) of safe houses, recruits, leaders etcetera, and the psychological which includes intelligence and local support. Finally, there is the issue of opportunity, which comprises of both geographic and temporal aspects.

Traditionally this model was seen as a linear triple hurdle model. This meant that the enemy had to clear all three hurdles before an attack could take place. This was incorrect. The true model is represented in the Venn diagram below. The linkages between the circles are the various flows that enable the synchronization of aim and action. Within each circle are agents who provide the capability, will and if need be the opportunity (although these may not be physical agents). Where the circles intersect, certain individuals will act as tags and from these will form groups for action. These links will form through the concept of emergence.

¹⁹⁵ Donald Chisholm, "The Risk of Optimism in The Conduct of War," *Parameters*, (Winter 2003-2004): 114-131. Available at <http://carlisle-www.army.mil/usawc/Parameters/03winter/chishol.htm>. Last accessed 25 July 2004. This article provided the genesis for this idea.

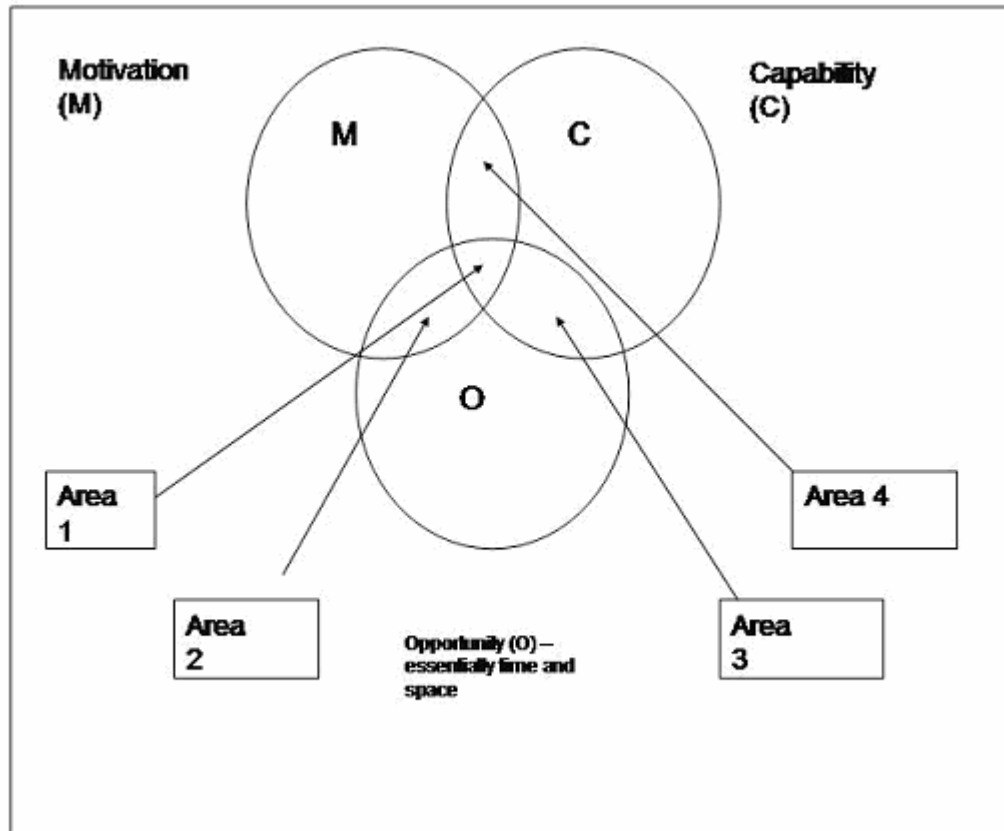


Figure 6: Venn Diagram Representation Of The Pillars Of Behavior Center of Gravity Model.

Using the diagram it can be seen that if the enemy system is in area 1 then attacks will occur. If in area 2 then attacks are only likely when gets the capability, something that can be monitored. Area 3 denotes the optimal place for an enemy from a deployed force's perspective as with no motivation there should be no threat. Finally, area 4 represents the second worst case for the deployed force as the enemy has the will and the capability and only needs to get lucky once to create an attack. The traditional approach of attrition has concentrated on the physical aspect only and has sought to remove this circle from the system. The doctrine of disintegration and the dislocation has concentrated on the psychological, again in the hope of removing it from the

system. Yet, the ability of a system to repair itself results in a system that is not totally destroyed becoming more complex through its experiences.

The three circles should be imagined as creating a CAS. In their constituent parts there is very little that would suggest that it is a COG. However, when these three elements join the emergent behavior is a source of strength that could not be predicted from the individual behavior. These elements are brought together by a number of factors. Agents within each circle operate through a mechanism of information flow and tagging to locate each other. The relative size of each circle represents the strength of that agent vis-à-vis the others. The trick to preventing the COG from being able to form is to prevent the three circles from forming a complex system.

If at any stage an element can be targeted to split the circles, the COG reverts from being an advanced CAS to a collection of at least two less developed CAS, which lack the emergent behavior required. This separation can be achieved by brute force (simply smashing one of the circles, something that traditional attritional concepts depended on), or by attacking the links that allow the CAS to form. As time progresses and the COG CAS is not influenced by external factors the overlap of the circles will grow, signifying an increase in complexity and redundancy of the COG. The circles can never fully overlap, as this would signify an invincible COG.

So how does one prevent the Center of Gravity from either forming or once formed from becoming complex? As with any CAS, there is a period at its forming when it is weak and vulnerable. The links between the circles have not been given time to form strong bonds and the agents are still capable of operating alone. It is possible at this point through the application of a relatively small amount of power to split the circles and thus render the CAS useless. The COG needs to have information and supplies in from the outside in order to continue to operate. It then takes these and through the process brought about by the creation of a CAS will create an output in turns of energy that can be used to either direct itself further along the fitness landscape, or against the enemy CAS, or both. Thus without its inputs the CAS is blind, and is forced to use its deplete its own energy far quicker than if it were an open system. This process is shown below.

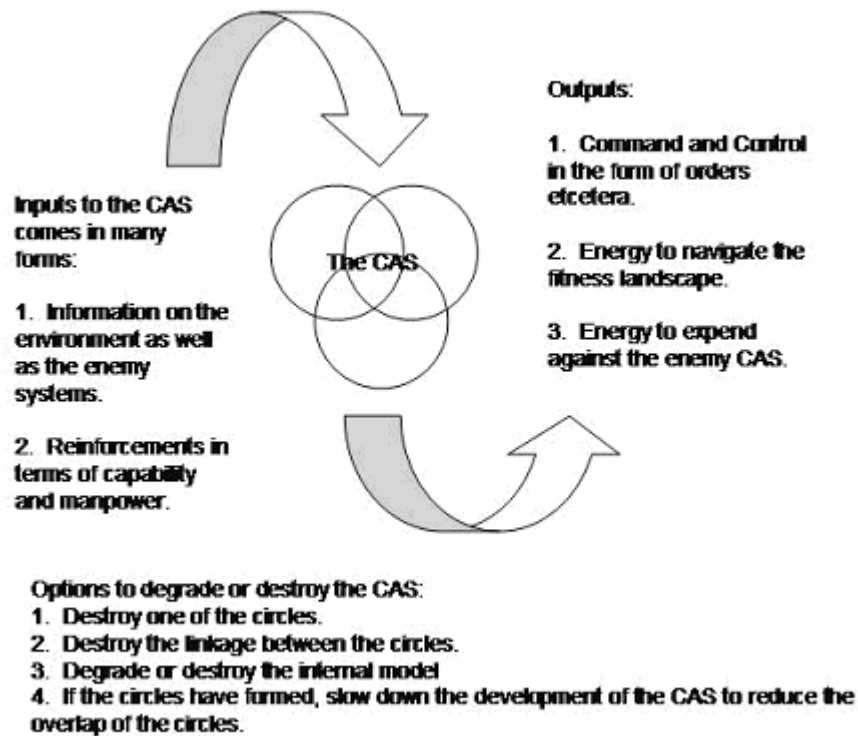


Figure 7: Diagrammatic Representation Of The CAS Within The Pillars Of Behavior Center Of Gravity Model.

By using a complexity lens to analyze a COG, one can analyze how to deal with it. This can be done in four ways; by changing the environment; by closing the system; by forcing it into equilibrium; or by forcing it into chaos. Each of these cases has been analyzed in the chapter 3. Overwhelming force should not be examined from the point of only physically attacking the enemy, but in a manner used to help change the environment. The aim of this is to either force the enemy system's internal model to change, or to create a condition where by an enemy CAS ignores the change in situation and reproduces itself with a flaw that forces it from a fitness peak toward a trough.

Attacks will only happen in the center region. Thus, armed forces attempt to break the linkages between circles. This can be achieved in several ways. The properties that the planner can affect are aggregation, flows, tags, and the internal model's power to anticipate. By stopping the circles joining the planner prevents aggregation. By severing the links the flows are interrupted (this can be the flows of equipment, orders or information). By preventing the enemy from being able to declare openly their loyalty then the friendly CAS prevents the use of tags to rally support. This will be an essential mechanism to prevent the forming of the agents into the CAS. This will need to be done on all levels and must include domination of the Electromagnetic Spectrum (EMS) as well as the physical domain.

The circles can be severed, either by stretching and breaking of the conduits between them; by physically shattering one or more of them; or by shrinking them so that they can no longer provide the overlap. The system can of course compensate for this by attempting to expend more of its energy into enlarging one of the shrinking circles, but this is inefficient. Traditionally one has examined how to deal with the capability aspect, as this is measurable, both before and after the event. The most direct but costly way of achieving this is via wholesale destruction. Maneuver warfare on the other hand attempt to deny it the ability to influence the battle, by dislocating the force, or by rendering its capability useless via an indirect means. Motivation was dealt with in both a kinetic and non-kinetic manner, and capability was rendered useless by not preventing an opportunity to influence the battle. Precision munitions sought to push the system into chaos and overwhelming force sought to dissuade commanders from attacking.

How can one measure if one is having an effect? Again, this was discussed, but as a reminder one can examine many variables. The first indication of success could be a change in the Modus Operandi (MO) by enemy. This would indicate that they had identified a change and thus their reaching a bifurcation point and that they need to make a change to remain adaptive. A current example is the change of the enemy tactics from outright targeting of US army bases in

Iraq to targeting the contractors (either by killings or kidnapping) and those of their own who are trying to become law enforcers.

The second type of change is identical to that discussed earlier when the system is pulled into chaos, and thus will not be discussed any further. The third change is actually not a change on the enemy's behalf at all, but a lack of a change by the enemy. This would only be ideal when the friendly force has changed in such a manner to warp the fitness landscape in a way that is negative to the enemy system. This will result over time in the enemy internal model continuing to plot a sub-optimal path through the fitness landscape, becoming less and less effective, and therefore more likely to become extinct.

Can culture have an effect? It appears so: the Japanese continued fighting long after the surrender by their Emperor, and would not have thought about stopping prior to this. Hamas, despite the regular successful Israeli incursions into their territory and removal of their leaders, does not appear to suffer from a reduction in volunteers. Mao incurred casualties beyond what could be considered by Western standards to be normal, and in the 1950s, the Korean human wave attacks were seen as fanatical. It is not just foreign cultures that exhibit this fanaticism either. Both the UK and France in World War I and Russia in WWII exhibited the ability to absorb huge losses without an apparent loss of resolve. This can be represented in the model by showing the will circle as being relatively larger than the other two.

Finally it is possible to remove some confusion over what exactly a Center of Gravity is if one uses a complexity model. Several planners claim that Centers of Gravity are Lines of Communications (LOCs). If one sees the Center of Gravity as a complex adaptive system (CAS) that develops over time this simply cannot be the case. The CAS is something that in combination with other factors is capable of causing some form of effect, both on its opposition and on the environment. LOCs do not do this. LOCs are the means of keeping a system open and thus enabling it to replenish its energy. If one can close the system by destroying the LOCs, the system has two choices, adapt or die. Even at a strategic level the CAS has to be something that is

capable of changing the fitness landscape. Such examples of ideology and will are acceptable, but again it has to be something that adapts over time.

This model is somewhat short and not robust enough to survive rigorous examination. This was not its purpose. Its purpose was to prove the usefulness of complexity theory in the field of operational design. While not suggesting throwing the baby out with the bath water, it is essential that all elements and concepts of operational design be examined through a complexity theory lens. Should applicability be found it should be studied in depth and if robust in nature, taught to planners. Ashby's law abounds everywhere. The more tools the planner has, the greater his variety, and thus the greater his ability to control another CAS.

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